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TWO DECADES OF PETROLEUM GEOLOGY, 1903–22

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INTRODUCTION

The science of petroleum geology as we know it today, has been principally developed since the beginning of the twentieth century, in large measure by members of this Association. Furthermore, it can be said that a large number of individuals have each added something to this new but important branch of economic geology. It is the purpose of this paper to call attention to some of the salient points in this march of progress and to show the influence which our science has had on the petroleum industry which it serves.

In preparing this review the writer has drawn freely upon the published works of his associates as well as upon his personal experience, which has spanned the two decades under discussion. To his friends and associates, whose work has made petroleum geology, and, hence, who are responsible for this paper, he extends his sincere thanks.

RELATIVE IMPORTANCE OF THE VARIOUS COUNTRIES IN OIL PRODUCTION, 1903 AND 1922

In order to show that the United States holds the premier place among the nations as an oil producer, and to indicate the relative position of all countries twenty years ago and now as indicated by their annual production, the following table, arranged

by countries in the order of their importance in 1903, is given. For purposes of comparison the year of their peak and the production for that year are also given.

TABLE I

PRODUCTION BY COUNTRIES, 1903 AND 1922

(In Barrels of 42 Gallons)

Country	1903	Peak of Production		1922
United States	100,461,337			551,197,000
Russia	75,591,256	(1902)	80,540,044	35,091,000
Dutch East Indies	5,770,056	(1920)	17,529,210	16,000,000
Poland (Galicia)	5,234,475	(1909)	14,932,799	5,110,000
Rumania	2,763,117	(1913)	13,554,768	9,817,000
India	2,510,259	(1917)	8,078,843	7,980,000
Japan and Formosa	1,209,371	(1915)	3,118,464	2,004,000
Canada	486,637	(1900)	913,498	179,000
Germany	445,818	(1910)	1,032,522	200,000
Peru	278,092			5,332,000
Mexico	75,376	(1921)	193,397,587	185,057,000
Italy	17,876	(1911)	74,709	31,000
Argentine	Began producing in 1907			2,674,000
Trinidad	Began producing in 1908			2,445,000
Egypt	Began producing in 1911			1,188,000
Persia	Began producing in 1917			21,154,000
England		(1919)	1,900	
France (Alsace)	Began producing in 1918			
Venezuela	Began producing in 1918			2,335,000
Algeria	Began producing in 1919			9,000
Sarawak	Began producing in 1920			2,915,000
Colombia	Began producing in 1922			323,000

In 1903 the United States produced 52 per cent of the world's total of 194,879,669 barrels; in 1922, 65 per cent of the world's total of 851,540,600 barrels. The increase in the world's annual production in the two decades from 1903 to 1922 was 337 per cent; the increase in the annual production of the United States over the same period was 451 per cent.

RELATIVE IMPORTANCE OF THE VARIOUS STATES IN OIL PRODUCTION, 1903 AND 1922

In order to show the relative importance of the oil-producing states in 1903 and 1922, as indicated by their annual production, the table on page 605 is offered.

The only states showing a consistent rise in production at the present time are California, Oklahoma, Texas, Wyoming, and Montana; all the rest are on a decline from peak production.

TABLE II

TABLE OF PRODUCTION BY STATES, 1903 AND 1922

(In Barrels of 42 Gallons)

State	1903	Peak of Production		1922
California	24,382,472			139,671,000
Ohio	20,480,286	(1896)	23,941,169	6,762,000
Texas	17,955,572	(1910)	8,899,266*	116,670,000
West Virginia	12,899,395	(1900)	16,195,675	7,028,000
Pennsylvania and New York	12,518,134	(1891)	33,009,236	8,443,000
Indiana	9,186,411	(1904)	11,339,124	1,443,000
Kansas	932,214	(1918)	45,451,017	31,588,000
Louisiana	917,771	(1920)	35,649,000	34,171,000
Kentucky and Texas	554,286			8,991,000
Colorado	483,925	(1904)	501,763	97,000
Oklahoma	138,911			146,631,000
Wyoming	8,960			26,232,000
Missouri	3,000	(1916)	17,705	
Illinois	Began producing in 1905	(1908)	33,686,238	9,363,000
Montana	Began producing in 1916			2,369,000

*Low point over twenty years.

ORIGIN OF OIL

The organic origin of oil, first suggested by J. S. Newberry[1] in 1873, and substantiated by Edward Orton,[2] and others, was well established by 1903 through observation and experiment. The original theory has been accepted by almost all geologists, except Coste. Since 1903 there have been some additional important discoveries regarding the subject.

C. B. Morrey,[3] 1903, suggested that bacterial action plays a part in the reactions yielding oil. Such bacteria are anaerobic, or capable of living without oxygen. W. H. Dalton,[4] in 1909, showed that there are two stages in the formation of petroleum from organic material; in the first, biochemical processes predominate; in the

[1] *Ohio Geol. Survey*, Vol. I (1873), p. 160.

[2] *Ibid.*, Vol. VI (1888), p. 74.

[3] *Ohio Geol. Survey Bull. 1* (1903), p. 313.

[4] *Econ. Geol.*, Vol. IV (1919), pp. 603–31.

second, geochemical or dynamochemical processes. David White,[1] in 1915, and D. F. Winchester stress the importance of plants of low orders in the origin of oil. George H. Eldridge, Robert Anderson, Harry R. Johnson, and the writer in their work on the California oil fields have clearly demonstrated that the principal sources of oil in California is free-swimming, microscopic, unicellular marine plants, called diatoms, many millions of which occupy a cubic inch. The contributions of Murray Stewart,[2] E. W. Shaw,[3] W. H. Twenhofel,[4] and others, with those mentioned above, not only show that oil is probably largely of plant origin but suggest the steps by which the intricate process may be carried out. The effect of dynamic movements on the processes of oil formation and accumulation have been pointed out by several geologists, including A. W. McCoy.

OCCURRENCE OF OIL

Through the development and study of numerous new fields and districts during the past twenty years, many new modes of occurrence as regards structure and reservoir rocks have been discovered. Edward Orton,[5] in 1889, was the first to point out commercial deposits of oil on structural terraces or "arrested anticlines." Captain A. F. Lucas in January, 1901, opened the first oil field on a salt dome (Spindle Top) in Texas. L. H. Woolsey,[6] in 1906, noted that oil occurs in synclines where the beds do not contain water. George H. Eldridge, Robert Anderson, H. R. Johnson, and the writer,[7] in 1907 to 1910, found that most of the oil in the California fields occurs on anticlines (85 per cent according to G. C. Gester) or monoclines sealed by asphalt or faults, or occurs actually in fault zones. E. DeGolyer, in 1915, reported oil in shattered shale above an igneous sill in the Furbero district, Mexico. From 1900 to date, C. W. Hayes, E. DeGolyer, G. Jeffreys, L. H. Huntley,

[1] *Jour. Wash. Acad. Sci.*, Vol. V (1915), pp. 189–212.

[2] *Rec. India Geol. Survey*, Vol. XI (1910), pp. 320–33.

[3] *Trans. Am. Inst. Min. Eng.*, Vol. LI (1915), p. 606.

[4] *Am. Jour. Sci.* (4th ser.), Vol. XL (1915), pp. 272–80.

[5] *Ohio Geol. Survey*, Vol. VI (1889), p. 94.

[6] *U. S. Geol. Survey, Bull. 286* (1906), p. 81.

[7] *Ibid.* (1907–10), Nos. 309, 398, 406.

V. R. Garfias, and others have found that oil in Mexico usually occurs in porous or cavernous crests of faulted anticlines or domes in association with igneous intrusions. C. W. Washburne,[1] in 1910, found oil occurring in fissures in the Florence field, Colorado. C. H. Wegemann[2] reported similar occurrences in the Salt Creek field, Wyoming, in 1917. The writer and his associates, and R. W. Pack, W. A. English, and W. S. W. Kew, in their various reports have called attention to the great importance of unconformities in oil accumulation in California.

Studies of sedimentation by Joseph Barrell, T. W. Vaughan, Marcus Goldman, and others have added information of great economic value to the industry.

Other students of geology have added much to our knowledge during the past twenty years in regard to irregularity of (spotted) production, due to variation in pore space in a given stratum; succession of petroliferous strata and the usually greater lateral extent of the lower oil-bearing sands or zones in any structure; distance covered in the migration of petroleum; minimum inclination necessary for migration; variation of dip at various depths in the same structure, due to unconformities and difference in lateral pressure, etc.

RELATIONSHIP OF WATER TO OIL

The theory of gravitational separation of gas, oil, and water, based on the difference in the specific gravity of the three substances, and known in general as the "anticlinal theory of accumulation," was placed on a substantial basis by I. C. White and Edward Orton long before 1903. This theory is demonstrated in so many fields, so widely separated, and under so many different conditions that further proof is unnecessary. However, many important discoveries and theories regarding the relationship of oil and water accumulation have been made in the past two decades.

M. J. Munn's[3] hydromotive theory, proposed in 1909, is that water in motion in underground channels carries the oil with it. This theory best explains the accumulations in many of the Penn-

[1] *Ibid.* (1910), No. 381.

[2] *Ibid.* (1917), No. 670.

[3] *Econ. Geol.*, Vol. IV (1909), pp. 509–29.

sylvania fields studied by him and W. T. Griswold, where the strict interpretation of the anticlinal theory does not hold good.

The observations and experiments of C. W. Washburne,[1] in 1914, regarding the importance of difference in surface tension as a factor in the segregation of oil and water, and his theories regarding the rôle and fate of connate waters in oil sands, have been a marked contribution to the theory of oil accumulation. Likewise, the experiments of A. W. McCoy,[2] who in 1919 showed that when oil-soaked mud is placed near water-soaked sand the oil will move to the sand, are enlightening as to what transpires during the formation of an oil pool.

The diffusion of crude petroleum through fuller's earth has been studied by D. T. Day,[3] J. E. Gilpin, and M. P. Craver,[4] who have reached important conclusions as to the resultant fractionation accomplished thereby.

To the late G. S. Rogers,[5] whose paper on the Midway-Sunset Field, California, in 1919, was monographic, must be given the credit for pointing out the importance of a detailed study of the occurrence and chemical examination of the waters accompanying oil accumulations. Rogers, N. M. Fenneman, C. W. Washburne, Johann Koenigsberger, Max Muhlberg, and others, from 1905 to date, have contributed to our knowledge of the temperatures of oil fields, largely through a study of their waters.

METAMORPHISM OF PETROLEUM

The fact that the fixed carbon contents of coals associated with oil and gas reservoirs furnished a remarkably reliable index of the probability of finding oil or gas in these reservoirs was first shown by David White[6] in 1915. M. L. Fuller[7] and J. H. Gardner[8] elaborated on White's discussion in 1917. Fuller[9] states that the

[1] *Trans. Am. Inst. Min. Eng.*, Vol. L (1914), pp. 829–42.

[2] *Jour. Geol.*, Vol. XXVII (1919), pp. 252–62.

[3] *Science* (new ser.), Vol. XVII (1903), pp. 1007–8.

[4] *Bull. U. S. Geol. Survey*, Nos. 365 and 475, 1908 and 1911.

[5] *Prof. Pap. U. S. Geol. Survey*, Part II, 1919.

[6] *Jour. Wash. Acad. Sci.*, Vol. V (1915), pp. 189–212.

[7] *Bull. Geol. Soc. Am.*, Vol. XXVIII (1917), p. 643.

[8] *Ibid.*, pp. 675–720.

[9] *Econ. Geol.*, Vol. XV (1920), p. 232.

relative probability of finding oil in proper reservoirs is 100 where the fixed carbon of coal is 50 to 55 per cent; 10 where fixed carbon is 55 to 60 per cent; and but 1 where fixed carbon is 60 to 65 per cent. The utilization of this information has saved much useless exploration work.

GAS PRESSURE AND OIL RECOVERY

Because of the fact that the principal controlling factor of oil production is the pressure of the gas associated in solution, or otherwise, with the oil, the study of the decline of wells resolves itself largely into a study of the declining gas pressure in these wells. Although many geologists, notably C. W. Washburne, R. H. Johnson, and others, had devised various means of showing production declines graphically, it remained for Carl H. Beal, in association with J. O. Lewis, to cover the subject thoroughly. Beal's paper was published as *Bulletin 177 of the United States Bureau of Mines* in 1919. Utilization of the methods summarized in this book has had a profound influence on the oil industry. One of the most important facts brought out by Beal's and Lewis' work was that wells of the same daily production in any one field can be depended on to yield approximately the same future production.

ESTIMATION OF OIL RESERVES

Twenty years ago the estimate of oil reserves was computed generally by calculating the contents of the supposed reservoir rock from data regarding thickness, extent, etc., guessing at the saturation and percentage of recoverable oil, and finally arriving at a very rough approximation of the desired information. Now, thanks to the great mass of data available and to the perfection of methods of computation, we get more accurate results. If we know the production of a given well over a reasonable period (even a period of days in some instances), we can calculate with remarkable accuracy the future production of the well by years and in totality, and thus arrive at the recoverable reserve for this well and its surrounding area.

May the writer not state that the estimation of oil reserves is the "king of indoor sports" of the petroleum geologist? The

habit was initiated by David T. Day,[1] in connection with the conservation movement espoused by President Roosevelt in 1908. Among the estimates so far made for the United States are:

TABLE III

	Barrels
1908, D. T. Day, minimum	10,000,000,000
1908, D. T. Day, maximum	24,000,000,000
1915, Ralph Arnold	5,763,100,000
1920, David White	6,740,000,000

The life of certain of the light gravity oil fields of Mexico has received some attention from E. L. Doheny and the writer. The latter[2] as early as February 1921, from information furnished by several of his associates, predicted with remarkable accuracy the great slump in production in 1922, due to the inroads of salt water and the exhaustion of certain of the pools. Eugene Stebinger[3] was the first to approximate the world's reserve; his figures in 1920 indicate a total of 43,005,000,000 barrels.

ADVANCEMENT IN GEOLOGIC METHODS

A steady and revolutionizing advance in field and laboratory methods of geologic study has been made by the petroleum geologist, largely over the last two decades. This advance has been so marked as to warrant the statement that the oil industry has contributed as much to certain branches of geology as geology has contributed to the oil industry. The trend of this advance has, like the drilling of deeper and deeper wells, been away from surface geology to subsurface work.

A great mass of detailed data regarding underground conditions has been given to science which never would have been made available except through the drilling of the thousands of wells put down in the search for oil and gas. Furthermore, the exactions of the industry for accuracy and detail in observation and deduction has tended to raise the science of geology from the realm of generalities toward the plane of mathematical accuracy. The credit for

[1] *Bull. U. S. Geol. Survey, No. 394* (1909), pp. 30–50.

[2] *Min. and Metallurgy*, No. 171 (March, 1921), p. 21.

[3] *Oil and Gas Jour.*, Vol. XIX (1920), No. 3, p. 54.

this last effect must be shared with the mining industry. Now the terms, "economic geology" and "economic geologist," imply extreme accuracy as well as practical and commercial value. On the other hand, many of the most important contributions to the oil industry through geology have been made as a result of studies primarily undertaken for scientific purposes only.

At the beginning of the century, maps showing the general features of geology and structure were the only ones in common use. Edward Orton,[1] in 1889, was the first to use subsurface-shaded contours to show the structure of an oil-bearing formation, the Trenton limestone. The first contour-line subsurface oil map to be issued was that by W. T. Griswold,[2] topographer of the United States Geological Survey, in 1902, showing the Berea grit oil sand in the Cadiz Quadrangle, Ohio. C. W. Hayes, in his letter of transmittal, said: "I believe this paper marks a distinct advance in the methods of studying oil fields and of determining and delineating the structures of oil-bearing formations." Now we use similar maps of extreme accuracy to depict not only structures but variations in temperature and metamorphism as well as specific gravity and other characteristics of the oil in underground reservoirs.

Extremely detailed mapping both surface and subsurface, by perfected plane-table and instrument methods are now in common use in the oil fields and are absolutely essential for good results in fields with low dips, like Oklahoma. For the development of the refinement of these methods we are largely indebted to the Oklahoma geologists. Accuracy in measurement of geologic sections, both subsurface and surface, with an accompanying detailed study of the composition and contents of the strata, have led to some remarkably valuable results.

The use of stereograms by C. H. Wegemann and K. C. Heald,[3] and large-scale peg models of oil fields by R. P. McLaughlin and Roy Collom, of the California State Mining Bureau, to show the details of underground geology in the oil fields, has been extremely useful in the education of the operators and the public.

[1] *Eighth Ann. Rep. U. S. Geol. Survey*, Part II (1889), facing p. 548.

[2] *Bull. U. S. Geol. Survey, 198*, 1902.

[3] *Ibid.* (1915), No. 621.

PETROLEUM GEOLOGY'S DEBT TO PALEONTOLOGY

Just as geology is the foundation of the petroleum industry, so is paleontology the key to petroleum geology. To those of you who now glibly use formation names and deftly make detailed correlations of sands and strata from well to well and field to field without the direct use of paleontology, the writer would say: "It would not be possible without the pioneer work of the paleontologist." Credit and thanks are due to the paleontologists for working out the broad correlations, and, in many instances, the minute details of stratigraphy upon which we base the expenditure of millions of dollars annually in development.

Among these pioneers are Charles D. Wolcott, David White, E. O. Ulrich, Charles Schuchert, G. H. Girty, E. M. Kindle, and Stuart Weller in the Paleozoic; T. W. Stanton, J. P. Smith, L. W. Stephenson, R. T. Hill, and E. T. Dumble in the Mesozoic; and T. W. Vaughan, W. H. Dall, G. D. Harris, E. W. Berry, J. C. Merriam, F. M. Anderson, C. W. Cooke, the writer, and others in the Tertiary. Of especial interest, and often of inestimable economic importance, is the work of R. S. Bassler, J. A. Udden, Jon Udden, Rufus Bagg, E. Call Brown, Albert Mann, E. R. Cumings, and others on the microscopic organisms, such as foraminifera, bryozoa, sponge spicules, diatoms, etc. The use of these minute forms in correlation has been developed within the past few years, is becoming more and more important with the improvement in methods of coring and is one of the major advancements in technique introduced by paleontologists.

The first use of plates of diagnostic fossils in an oil bulletin was by the writer, in 1907, in the report of G. H. Eldridge and himself[1] on the oil fields of southern California. Now such use is not unusual. A. Beeby Thompson, the English geologist, told the writer that he had used the plates in the California oil bulletins in correlating the various Tertiary horizons in the oil fields of Peru.

PETROLEUM GEOLOGY AS A PROFESSION

The term, "petroleum geologist," has been coined in the last few years to designate those geologists who have specialized on

[1] *Bull. U. S. Geol. Survey* (1907), No. 309.

oil and gas. These men simply applied the knowledge of geology and related sciences to an industry, the development end of which up to twenty years ago had been conducted along the lines of "hit or miss," "rule of thumb," or "hunch."

I. C. White was probably the first geologist to devote his entire attention to the petroleum industry. This was in 1892. E. T. Dumble was a close second. The next to hang out his shingle as an oil geologist was A. C. Veatch, in Beaumont, Texas, in 1901, following the excitement of the Spindle Top discovery. In 1908 F. G. Clapp left the government service and opened an office in Pittsburgh, followed later by W. T. Griswold, the writer, and several other venturesome spirits who were willing to risk the plunge from a sure government pay check to the uncertainties of a professional career. The writer believes he was the first American oil geologist to go after the foreign trade by opening an office in London in 1911.

ATTITUDE OF THE OIL OPERATORS TOWARD PETROLEUM GEOLOGY

Twenty years ago a geologist was just as welcome in a drilling rig as a "hornet at a garden party." The oil men were prejudiced against us. When one sizes up some of the freaks and impostors who have posed as geologists, can we blame the oil men? But the latter have learned to separate the "sheep from the goats," so now we, as a group, are coming into our own. Only a few years ago I heard President J. C. Donnell, of the Ohio Oil Company, say: "When the geologist comes in to the oil industry, I go out." Now the geology department is one of the most important in the Ohio Oil Company. Less than ten years ago Fred H. Hillman came out here from a series of successes in the then-booming Illinois fields, to assume charge of the producing department of the Standard Oil Company, of California. On arrival here he announced: "Oil is where you find it," and proceeded to acquire a lot of leases on which he drilled ten test wells. They were all dry. Now Mr. Hillman has one of the best geological departments in the world, and is himself the biggest booster for geology on the West Coast. It takes big men to put aside prejudice and get the other fellow's viewpoint. Has it paid? Ask our friend G. C. Gester; he knows.

Look at Montebello, Huntington Beach, and Wheeler Ridge, and the other successful wildcat operations of the Standard, all of which have been brought in since the company established an up-to-date geological department. Thus have the operators one by one come to bury their prejudices and recognize the value of geology, not only by employing large staffs of geologists but by depending on them for the choice of properties and location of wells, two of the most important items of the industry.

Much of the credit for the success of the Union Oil Company, of California, is due W. W. Orcutt, the dean of California oil geologists. Even Tom O'Donnell now has a pet geologist, and that is the last word. The old Kern Trading and Oil Company (now Pacific Oil Company), largely through the influence of E. T. Dumble and A. C. McLaughlin, has always been one of the leaders in applying scientific methods to oil recovery.

INFLUENCE OF GEOLOGISTS ON OIL INDUSTRY

When the writer first entered the California fields, he was advised, often in forceful language, that the only essential in a well log was the depth to the top and bottom of the oil sands. Water a menace? "Well, not in our field; possibly somewhere else." Now, all is different. The operators have come to realize that if they are to exact accurate information from the geologist, the latter must be furnished with reliable data. As an outgrowth of this, we have the coring system in vogue in the California fields today, where actual samples of the rock are taken intact for careful examination and analysis of organic or chemical content. The Shell Oil Company, of California, J. E. Elliott, R. B. Moran, and E. Call Brown are largely responsible for this refinement of technique.

In like manner, a close co-operation between the producing departments and geologists has resulted in the keeping of more and more detailed records of production, especially of individual wells, so that now the decline curves computed by the geologists are more accurate, and hence the estimates of reserves used for tax computation and many other purposes are more reliable. Many other improvements in the technology of oil development, such as the making of water shut-offs, testing for water trouble, etc., may

be ascribed to the influence of the geologist. J. O. Lewis and his associates are revolutionizing the recovery methods in some of the Appalachian fields.

INFLUENCE OF PETROLEUM GEOLOGISTS ON BUSINESS

Without appearing to be prudish, may we not say that the influence of the petroleum geologist on the business standards of the industry has been good? Somehow a scientific training tends to make the student revere the ethical ideals a little more than does the ordinary business training. As a result, it can be truthfully said that few geologists make good business men. The tendency of the geologist to state the facts, no matter what the result, has given him a high rating for dependability, even if not for good judgment in every case. The fact that corporation control, as related to oil and mining in most of our states, is based primarily on the work of engineers and geologists, speaks volumes for the dependability of the men of these professions. The standards suggested by F. G. Clapp, in his *Ethics of an Oil Geologist*, and those adopted by the American Institute of Mining Engineers and the American Association of Petroleum Geologists have been so high as to place our profession among the leaders in business morals.

Furthermore, our profession has had a beneficial influence in systematizing and standardizing many lines in the oil and gas industry, such as the keeping of records, accounting, computing of depletion, depreciation, amortization, the segregation of capital and operating expense accounts, etc. And occasionally a geologist makes a good oil-company executive.

EXPLORATION WORK AND "WILDCATTING"

Whereas the search for oil at the beginning of the period we are discussing was carried on in a small, unsystematic way, largely by local groups organized solely for making a single test, today we find exploration as highly systematized as any branch of the oil industry. The influence of geologists in this regard has greatly reduced the hazard of test drilling. It must be admitted that our British brethren took the lead in systematic exploration, especially in foreign lands, long before we attempted it, so that to them we

owe some of our ideas regarding exploration. The digging of test trenches and pits and the boring of shallow holes for the discovery of favorable structures or direct evidence of oil, are among their contributions to our technique.

With the entry of the Standard group of oil companies into the production of oil, beginning about sixteen years ago, exploration took on a new impetus, and up to the present time has maintained a strenuous pace. Among the larger exploration activities under the direction of geologists might be mentioned those of the general Asphalt Company and subsidiaries in Trinidad and Venezuela, begun under the direction of A. C. Veatch in 1911, and later continued by the writer with forty associates; that of the Standard Oil Company, of New York, in China in 1914–16, under the direction of G. D. Louderback; that in Kansas in 1916 by the H. L. Doherty interests, employing 200 geologists in a "drive" for new oil fields; and still later the extensive activities in foreign fields of the Standard Oil Company, of New Jersey, under C. F. Bowen, and those of the Sinclair Oil Company, under A. C. Veatch, who for several years following 1912 directed the exploration work of the Lord Cowdray interests of London. The exploration successes of E. DeGolyer and F. Julius Fohs have shown what remunerative results can come from a combination of geologic knowledge and good business judgment. The pioneering work of the United States Geological Survey and several of the state surveys has also been influential in opening up many new fields.

Volumes could be written regarding this phase of the petroleum geologist's work—probably the most important phase, if you please—of the hardships endured, difficulties overcome, and the dangers braved. Yet with all these trials and tribulations it has had its reward in the enjoyment of opening the trails of development and progress and of solving the many problems of virgin territories. Let us bow our heads for a moment in respectful remembrance of those of our associates who have gone down on the "firing line" in far-off lands—for men like Walter Knobbs, who died in Venezuela in 1912, and G. S. Rogers, who was drowned in Columbia in 1920—as true heroes as any who ever died for a righteous cause.

Systematic exploration has proved beyond any question that it can be carried out successfully only by operators with large capital and much perseverance. This has been recognized in at least one instance by several large corporations organizing a common exploration company. Between the pioneering of the oil companies for new business and new oil fields, the American flag has been introduced into more places in the world outside of the United States by the oil industry than by any other single agency.

THE CONSERVATION MOVEMENT AND THE LEASING SYSTEM

The suggestion to conserve our natural resources, initiated by Gifford Pinchot in connection with our forests, and espoused by President Roosevelt, was antedated many years by C. A. Ashburner[1] in "The Production and Exhaustion of the Oil Regions of Pennsylvania and New York." The Roosevelt policy, however, was carried actively into the realm of petroleum and gas in 1906 by I. C. White, C. W. Hayes, David T. Day, and others. White called attention to the waste of our fuel resources, including oil and gas, before the conference of governors at the White House, May 13–15, 1908. Day, as mentioned elsewhere, prepared an inventory of our national oil reserves at the same time.

In 1907, A. C. Veatch went to Australia to study the government land-leasing laws of that country. From the time of his return in 1908 to the passing of the oil-leasing act of February 25, 1920, there was a continual fight on between the proponents and opponents of the leasing system. The writer wishes to state here that if the radical anti-leasing group had listened to the suggestions of their conservative friends in and out of the government service, the leasing bill, with far more liberal terms to the operator than those that now prevail, would have been placed on the statute books. For instance, the maximum royalty probably would have been 5 per cent instead of "all the traffic will bear," as at present.

The writer had the questionable honor of suggesting the first withdrawal of public land from entry in 1907. The suggestion was promptly put into effect by President Roosevelt. This measure withdrew land classified as "mineral" from homestead entry, and

[1] *Am. Inst. Min. Eng.*, Vol. XIV (1886), pp. 419–27.

was designed to protect bona fide wildcat drillers from fake homestead entrymen. The conservation movement had assumed such influence in 1909 that President Taft on September 27 of that year withdrew large areas of mineral land from entry, pending passage of the leasing bill; and on July 3, 1910, he made further withdrawals under sanction of Congress, which tied up much of the oil land of the West for ten years. The classification of the withdrawn lands was made by the geologists of the Land Classification Board of the United States Geological Survey, originally organized by A. C. Veatch, and for many years headed by W. C. Mendenhall. Max Ball, A. R. Schultz, C. A. Fisher, and several other Rocky Mountain geologists were likewise engaged in this work.

The petroleum geologist has always stood for conservation as defined by C. W. Hayes, "Utilization with a maximum of efficiency and a minimum of waste." At the suggestion of J. A. Holmes, one of the early technical papers written for the United States Bureau of Mines was that on "Wastes in the Production and Utilization of Natural Gas, and Means for Their Prevention,"[1] by F. G. Clapp and the writer.

PETROLEUM GEOLOGY AND FEDERAL-INCOME TAXATION

Probably one of the most important contributions to the oil and gas industry in the last two decades was that made during the war by the ninety-odd petroleum geologists and engineers associated with the writer, then chief of the Oil and Gas Division, Bureau of Internal Revenue, who, at great personal sacrifice, gave up their personal work and came to the assistance of this government Bureau. Theirs was the problem of devising methods of computing depletion allowances, so that the taxpayers of this industry of wasting assets might deduct that portion of their gross profits from production which represented a return of capital, so that only their real profits might be taxed. Without going into details, it may be said that after breaking down many of the antiquated precedents of the Treasury Department, and overcoming equally obstructive prejudices on the part of many members of the industry, a method of making proper deductions, based on the

[1] *Tech. Pap. No. 38. U. S. Bur. Mines* (1913), pp. 29.

estimation of oil reserves, was finally adopted and put into effect. The details of this method were incorporated in the *Manual for the Oil and Gas Industry*, prepared by these men and published by the Treasury Department in 1918. Since that time many petroleum geologists have found employment in assisting the operators in solving their tax problems. In this instance the industry was saved from the almost certain ruin which faced it under a rigid enforcement of the drastic-income and excess-profits tax law of 1917 by the application of scientific methods to this very complex problem.

PETROLEUM GEOLOGY AND THE WORLD-WAR

It has been said that the allies "floated to victory on a sea of oil," meaning that the abundance of petroleum for their ships, automobile transports, and aeroplanes enabled them to outmaneuver the enemy. The part that the petroleum geologist played in speeding up the production when it was needed is familiar to all who were intensively engaged as consulting or company geologists during those trying times. We were prepared to meet the call and indicate the places where the oil was to be obtained and to co-operate with the producers in getting it out speedily. The names of M. L. Requa, W. A. Williams, Chester Naramore, and others, of our associates, as well as those of A. O'Donnell and S. A. Guiberson, Jr., will go down in history as those who helped "deliver the goods."

When H. P. Cady and D. F. McFarland[1] recorded the discovery of helium gas in certain wells in Kansas in their paper on "Chemical Composition of Gas," the statement aroused only academic interest, but when, during the war, the demand for this gas for inflammable balloons and airships became acute, it was the information first obtained by these men that enabled the United States Bureau of Mines, under the directorship of Van H. Manning and J. O. Lewis, chief petroleum technologist, to establish plants for its commercial recovery in the Mid-Continent field.

Lest we forget, let us also pay tribute to those of our group who donned the khaki and went to the front, many never to return. An illustrious example of the latter was J. D. Irving, professor of economic geology at Yale and editor of *Economic Geology*.

[1] *Kan. Geol. Survey*, Vol. IX (1908), pp. 228–302.

FEDERAL AND STATE SURVEYS AND OIL GEOLOGY

The foundation of the federal and state surveys' interest in oil geology was laid in the early seventies, when J. S. Newberry wrote about the oil fields of Pennsylvania, West Virginia, and eastern Ohio in the publications of the *Ohio Geological Survey*[1] and was continued on through the eighties, when Edward Orton in publications of the same *Survey* discussed the origin and accumulation of oil and gas.[2] In the middle and late nineties, W. L. Watts wrote the first reports on the California oil fields for the California State Mining Bureau. Practically all of the field work and issuance of the resultant publications on petroleum geology of our federal and state surveys, as we know them now, have taken place in the last two decades. The first separate oil report issued by the United States Geological Survey was *Bulletin 184*, by George I. Adams, on the oil fields of Texas, issued in 1901.

The United States Bureau of Mines, since its organization in 1910, has lent every effort in the way of experiment stations, investigations, and publications toward furthering the interests of the oil industry. The writer feels that he voices the sentiments of the great oil fraternity when he states that the United States Geological Survey and the United States Bureau of Mines, through the agency of their members and former members, have contributed as much to the economic development of the oil and gas industry of the world as all the other agencies combined. Much of the credit for this must go to the late C. Willard Hayes, chief geologist of the Survey, and to the late J. A. Holmes, organizer and director of the Bureau of Mines, and the men who have since occupied their positions.

Most of the oil-producing states have carried on important investigations, and published instructive and useful maps and reports relating to oil and gas. Among the noteworthy contributions to the science of petroleum geology and technology by the states are those of Edward Orton and J. A. Bownocher, Ohio Geological Survey; R. S. Blatchley and F. H. Kay, Illinois Geological Survey; C. N. Gould, Frank Buttram, L. L. Hutchinson,

[1] *Ohio Geol. Survey*, Vol. I, 1873. [2] *Ibid.*, Vol. VI, 1888.

D. W. Ohern, C. W. Shannon, and others, Oklahoma Geological Survey; and R. P. McLaughlin, California State Mining Bureau.

PUBLICATIONS ON PETROLEUM GEOLOGY

Except for a few reports in government or state publications, some scattered scientific magazine articles, and references in text-books on geology, there was practically nothing in print touching on the geology of petroleum at the beginning of this century. Boverton Redwood's monumental "Petroleum and Its Products," which came out in 1896, was the first great treatise on the subject in English.

With the entry of the United States Geological Survey into the intensive study of economic geology came a series of epoch-making bulletins on the oil fields of the Appalachian, Gulf, Mid-Continent, and California fields, and soon after its founding, in 1910, the United States Bureau of Mines began its important series of technical papers on "The Technology of Production and Utilization of Petroleum." These two series of publications without doubt have had a tremendous influence on the oil industry. To these federal publications should be added the many contributions to petroleum geology and technology found in the state publications, the most important being those of California, Illinois, Ohio, Oklahoma, Texas, and West Virginia.

Oil Production Methods, by Paul M. Paine and B. K. Stroud, 1913, was the first compact fieldbook containing an outline of petroleum geology. Then followed E. H. Cunningham-Craig's *Oil Finding*, issued in London in 1914. The first edition of Dorsey Hager's *Practical Oil Geology* appeared in 1915. Admitting such shortcomings of this volume as any young author is liable to make, the writer still believes that this little book has had a great influence in popularizing geology among the drillers and operators. Of late years many important volumes relating to oil geology and technology have come from the press. Among them might be mentioned A. Beeby Thompson's *Oil Field Development*, London, 1916; Johnson and Huntley's *Principles of Oil and Gas Production;* Bacon and Hamor's *The American Petroleum Industry*, 1916 (geology by Clapp, Johnson, and Huntley); W. H. Emmons' *Geology of Petro-*

leum, 1921; *Hand Book of the Petroleum Industry*, 1922, by D. T. Day and others; V. R. Garfias' *Petroleum Resources of the World*, 1923; Victor C. Alderson's *Oil Shale Industry*, and many others.

Two decades ago there were no serial magazines specializing in petroleum geology; now there are two serial bulletins (*Bulletin of the American Association of Petroleum Geologists* and *Institute of Petroleum Technology Division of the American Institute of Mining and Metallurgical Engineers*) devoted exclusively to oil geology and technology, and more than twenty magazines, journals, and bulletins devoted in a large measure to publishing the papers of the petroleum geologists and technologists.

PROGRESS IN OIL AND GAS EDUCATION

So far as the writer is aware, there were no institutions of learning giving any special courses in petroleum geology twenty years ago. According to R. H. Johnson,[1] one of the leaders in educational work in our profession, there are now at least thirty-four institutions of collegiate standing with special courses in petroleum geology and technology. The number of courses run as high as 13 (University of Pittsburgh), the number of class hours up to 468 (same institution), and the number of students specializing in this subject in a single institution as high as 60 (Stanford University). The writer is under the impression that some institutions now give a degree in petroleum engineering, and at least one, the University of Pittsburgh, has granted honorary degrees for meritorious work in oil geology.

No two people will ever rank the influence of the educational institutions on the oil industry in the same order; the writer's estimate is: Stanford University, University of Oklahoma, University of California, University of Chicago, University of Pittsburgh, Columbia University, and University of Kansas. The Colorado School of Mines stands alone in its specialty—oil shale.

The writer has endeavored to list those educators who have been most responsible for the advanced position of petroleum geology at the present time, but it is a hopeless task. To each of us our own particular teachers are the ones who should receive the credit;

[1] *Min. and Metall.*, Vol. CLXXXVI (June, 1922), p. 25.

and we are all right. It is a wonderful commentary on the preparedness of the geology and engineering departments of our institutions that they could so quickly, practically within the last decade, meet the heavy requirements of the great oil industry.

ORGANIZATION OF PETROLEUM GEOLOGISTS

Two decades ago there were no organizations of petroleum geologists, because there were practically no petroleum geologists to organize. Today there are many organizations supported in whole, or in a large measure, by members of our profession. The American Institute of Mining Engineers was the first organization to recognize the importance of oil geology and technology by creating a committee on oil and gas in 1916, under the chairmanship of Captain A. F. Lucas. In 1920 the writer succeeded Captain Lucas. In 1922 the status of the oil and gas group was changed to that of a division of the Institute, and then in 1923 to the Institute of Petroleum Technology Division, with E. DeGolyer chairman. Active sections of the Division are found in New York; Tulsa; and Tampico, Mexico. The papers of this Division, which have been numerous and important, are published by the Institute.

The American Association of Petroleum Geologists was organized in 1917 to meet the needs of the ever growing horde of petroleum geologists in the Mid-Continent field. From a charter membership of about 150, the organization has grown to over 1,000 members. The presidents of the organization have been: Alexander Deussen, I. C. White, W. E. Pratt, W. E. Wrather, and Max Ball. C. E. Decker has been the secretary. The Association publishes an excellent bulletin under the editorship of Raymond C. Moore.

The Society of Economic Geologists, organized in 1920, is made up in large measure of petroleum geologists, while the Southwestern Society of Petroleum Geologists, a semi-professional, semi-social society, is exclusively devoted to our profession. In addition to these there is the Branner Club, of Los Angeles, with over 100 members; the Le Conte Club, of San Francisco; and several local organizations throughout the country, made up exclusively, or in large part, by petroleum geologists. The British Institute of Petroleum Technologists is the largest and most influential foreign organization in our profession.

The influence of these organizations, in fostering meetings, discussions, and the issuance of publications, in establishing and maintaining standards of professional conduct, and in advancing the interests of the profession, has been such that the oil geologists, as measured by the membership of these organizations, rank among the best of the American professional groups.

CONCLUSION

Summarizing, we look back over twenty years of steady progress in our profession; of recognition coming to us because we had the foundation based deeply in science, which enabled us to respond to the call of a great and growing industry when it needed our help. We have grown with the industry; we have gained influence in the industry only as we earned it; we have profited only as we have made the industry a greater profit; and we hold the respect of the industry because it believes we are "square shooters."

What has the future in store for petroleum geology, or better, what has petroleum geology in store for the future? We must study proved fields more carefully for more reliable data on which to base our direction of exploration and test drilling, so as to reduce the hazard. We must strive for improvement in technique all along the line of operation. We must fight for conservation and the complete annihiliaton of waste in production and consumption; and, lastly, we must impress upon the industry and the public, morn and noon and night, the fact that our oil reserves are being rapidly depleted, and that only by improved methods of utilization, with a consequent increase of efficiency, will our domestic oil supply and all that we can bring in from foreign sources be sufficient to meet the requirements even of the immediate future. And we must do this last in the face of the present great overproduction. It is some job, but it will be done.

THE ROBBERSON FIELD, GARVIN COUNTY, OKLAHOMA

A. R. DENISON
Tulsa, Oklahoma

INTRODUCTION

The Robberson oil field with an average daily production in July, 1923, of 6,400 barrels from 174 wells, at that time ranked fifth among the producing fields in southern Oklahoma. This fact, together with the highly productive but short-lived gushers and large gas wells, makes the field of general interest.

ACKNOWLEDGMENT

The writer wishes to express thanks to the operators in the field who have co-operated in the collection of samples and from whom he received valuable information regarding production. Especial thanks is due to the Texas and Pacific Coal and Oil Company, who placed all their information at his disposal. The writer is indebted to a number of people with whom he has discussed the problems, especially R. H. Benton, of the Humble Oil and Refining Company, Dr. J. B. Umpleby, University of Oklahoma, and R. R. Thompson, Texas and Pacific Coal and Oil Company.

Dr. Sidney Powers has criticized the manuscript and has given many valuable suggestions.

LOCATION

With the exception of one small well in 19, 1 N., 2 W., the field is located in Sections 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, T. 1 N., R. 3 W., in the southwest corner of Garvin County. It is 28 miles southwest of Pauls Valley and 30 miles east of Duncan. The nearest railroad point is Wynnewood, 22 miles northeast, on the main line of the Atchison, Topeka & Santa Fe. It is 10 miles northwest of the Arbuckle Mountains and almost in line with the projected axis of folding of the Mountains. The Fox field is 12

miles south and the prolific Healdton field 20 miles directly south. The field is reached by improved roads from Pauls Valley and Wynnewood and by partially improved roads from Duncan.

HISTORY

Gas was discovered in April, 1920, by the Magnolia Petroleum Company, Cowan No. 1, NW. corner SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ Sec. 15, T. 1. N., R. 3 W. It struck 1,000,000 cubic feet of gas at 1,112–1,116

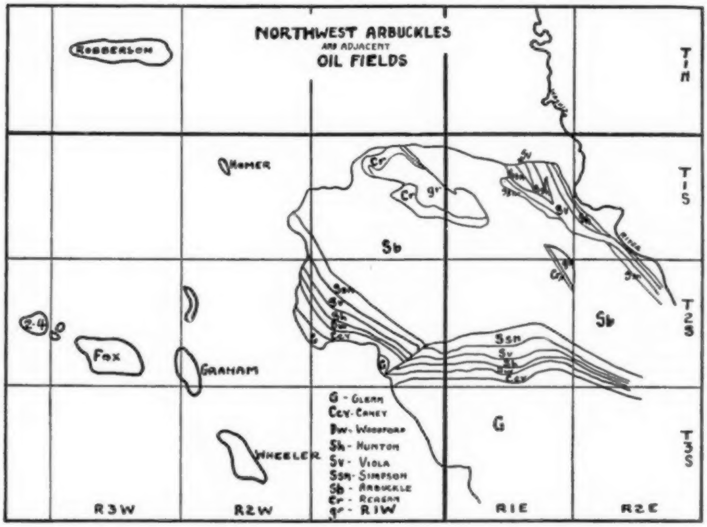


FIG. 1.—Northwest Arbuckles and adjacent producing fields

feet. The gas was used in drilling Mauldin No. 1, NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ Sec. 16, and was exhausted before the latter well was completed. The first big gas well to be completed was this Mauldin No. 1, which came in June 9, 1920, estimated at 40,000,000 cubic feet, from a total depth of 1,386 feet. Following this an active drilling campaign was started on adjacent property and during the next 13 months many gas wells in Secs. 15 and 16 were completed. Most of them reached the gas sand of the Mauldin No. 1.

Oil was discovered in Magnolia's Hart-Newberry No. 1 in the NW. corner of Sec. 14 on July 16, 1921, more than a year after the discovery of gas. This well was estimated to yield 200 barrels and stimulated a drilling campaign which led to finding oil in Secs. 15 and 16 near the original gas. Development progressed around two centers of production until they were connected by producing oil wells. The first large producer was the Texas and Pacific Coal and Oil Company's No. 1 Pearce in the NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ of Sec. 13, which came in August 16, 1922, good for 1,000 barrels daily; previously no well had made more than 250 barrels daily. This well gave the field the greatest impetus of any discovery, and was followed by the finding of two wells, each making more than 8,000 barrels daily.

STRATIGRAPHY

SURFACE

Surface exposures of the Robberson field are all of Permian age. They consist of alternating shales and sandstones, the latter sometimes grading into conglomerates. The shales are largely brown, but occasionally blue or gray beds occur for short distances usually grading into the characteristic brown beds. The sandstones carry much iron oxide which when weathered give a salt and pepper effect. Occasionally crystals of feldspar large enough to be recognizable are found in the sandstones and the conglomerates usually carry weathered fragments of feldspar. A bituminous sandstone outcrop has been reported in Sec. 24 and another in the SE. cor. Sec. 16.

SUBSURFACE

Permian.—Alternating layers are penetrated by the drill for the first 1,200 feet, here named the Garvin beds. They consist of "red beds," gumbo, and gravel with one or two limestone beds, one of which occurring from 950 to 1,000 feet is recorded as present in most of the early wells drilled, for which more accurate logs were made. This series carries a few water sands near the surface which have a good supply of potable water. The lower part is barren save for an occasional show of heavy oil. From 1,200 to 1,400 feet, a series of gas sands, alternating with red and blue shales, occur, called the Mauldin producing horizon after the original

large gas well. The sands appear to be lenticular and for that reason correlation is difficult even in offset wells. In the western part of the field adjacent to the original discovery well three gas sands are recognizable; the lowest, however, is the most prolific and is the one to which most of the gas wells have been drilled. In the eastern part of the field only one persistent gas horizon is recognized. It is, however, more persistent, and can be contoured within its limits of production. This sand where samples were obtained proved to be composed of fine to coarse, well-rounded sand grains.

The Garvin and Mauldin series above mentioned are of Permian age. Below these, various ages of rock are encountered in different parts of the field, ranging from Permian to possible Cambrian. The Robberson buried hills, of older rocks below an unconformity are present underneath the field, and are composed of steeply dipping limestone, sandy lime, sandstone, and igneous rock. Around the edges of these hills, at a depth varying from 1,375 to 1,877 feet, occur the Newberry "sands," named from the discovery oil well. These sands are also of Permian age but older than the Garvin and Mauldin beds.

Pre-Permian.—Because of the highly folded and possibly faulted condition in the "Robberson Hills," offset wells frequently encounter entirely different formations when drilled below the Permian. Determination of the age of the strata is uncertain, but they are assumed to represent a portion of the section exposed in the nearby Arbuckle Mountains. A fragment of limestone shot from the Texas and Pacific Coal and Oil Company's Mays No. 3, SW. Cor. N. $\frac{1}{2}$ NE. $\frac{1}{4}$ SW. $\frac{1}{4}$, Sec. 14, from a depth of 1,630 feet was sent to Dr. Charles Schuchert, who, finding a fossil fragment, referred it to Professor P. E. Raymond of Harvard. It was identified as the tail of a trilobite of the genus Phaeton, family Proetidae, probably an undescribed form. Dr. Schuchert classed this form as Silurian, probably St. Clair marble of the Ozarks, making it the equivalent of the Hunton formation in the Arbuckles. The Hunton formation is productive in two wells drilled near Maud, Oklahoma, fragments from these wells being identified by Dr. Galloway of Columbia and Dr. Schuchert[1] of Yale. The Misener sand produc-

[1] George D. Morgan, "A Siluro-Devonian Oil-producing Horizon in Southern Oklahoma." *Circular 10, Oklahoma Geol. Survey.*

tive in T. 15 N., R. 10 E., and adjacent territory has been referred to the same age as the St. Clair and Hunton. The strata penetrated in other parts of the field beneath this limestone do not show lithologic characteristics resembling the section below the Hunton as exposed in the Arbuckles but conforms closely with the Simpson formation and such interpretation would place the limestone as Viola, which lies just below the Hunton. The Simpson and Viola were known to contain petroliferous deposits, numerous asphalt quarries in these beds occurring in the Arbuckle uplift, also some of the production from Healdton and Hewitt is thought to come from these two formations, particularly the Simpson.

One well, the R. Newberry No. 2, Acc. No. 2 of the Texas and Pacific Coal and Oil Company in Sec. 13, has encountered igneous rock at a depth of 1,745 feet. The samples show a very fine-grained, slightly porphyritic felsite, containing some phenocrysts of quartz visible to the naked eye. The color varied with depth; the first 60 feet was pink and not difficult to drill; and the next 60 feet was dull black becoming harder with depth. Below this the drill penetrated 254 feet that was uniform brick red in color and which drilled very hard. Two other wells may have encountered igneous rock; the south offset to the above well stopped in black "lime" at 1,805 feet, and the Texas and Pacific Coal and Oil Company Weaver Bradfield well in Sec. 24 may also have igneous rock as it was shut down at 2,205 in black "lime," but no sample was available from either of these wells for comparison. The age of this igneous rock is doubtful but since it resembles the Colberts porphyry of the Arbuckle Mountains it is considered of pre-Cambrian age, although it might represent an intrusion of much later time.

Wells drilled at succeeding greater distances from the buried hill find an increasing thickness of "red beds." The deepest well in the field, Magnolia Petroleum Company Hodges No. 1, Sec. 9, encountered "red beds" to a depth of 2,645 feet where it passed into a broken limestone, which continued to 4,275 feet. Samples from this lime look like the lime found in the buried hill which is probably the Viola.

In two wells drilled down the flanks of the buried hill the "red beds" are thinner. Broadgate's Abrams No. 1, SW. $\frac{1}{4}$ SE. $\frac{1}{4}$

Sec. 23, T. 1 N., R. 3 W., passed out of "red beds" at 1,295 feet and encountered blue shale and shells to a depth of 2,115 feet. Alternating beds of sandy shale, shale, and lime are reported from 2,115 to 2,910 feet, limestone from 2,910 to 3,016 feet, the total depth. Magnolia's Downey No. 1, NE. ¼ NE. ¼ Sec. 22 T. 1 N., R. 3 W., passed out of "red beds" at 1,825 feet and encountered blue shale with a few limestones to a depth of 2,780 feet. This well stopped in a water sand at 2,840 and did not encounter the heavy limestone series found in other wells. These two wells may have encountered rocks of Pennsylvanian age below the Permian, for although no samples were secured the section below the "red beds" resembles known Pennsylvanian in other southern Oklahoma fields.

STRUCTURE

SURFACE

The surface structure is very difficult to work because of scarce and unsatisfactory exposures. The several geologists who have mapped the structure agree only regarding the south dip in Secs. 24 and 23 and southwest dip in Sec. 16. Correlation of beds on the south side of the field with those on the north is difficult due to the alluvium-filled valleys of Salt Creek and its tributaries which run through the center of the field.

This region has long been considered to have petroleum possibilities. G. H. Eldridge in a report of asphalts and bitumens in the *Twenty-second Annual Report of the U. S. Survey*, (1901) says in part:

> At the western end of the Arbuckle Mountains in the vicinity of Hennepen, Homer and Elk and even as far west as Robberson a number of seepages in water wells and springs or prospect holes are reported. These were accepted by the writer as evidence of the general distribution of oil and gas in as yet undetermined quantities. . . . . A specimen reported from the Robberson occurrence indicates it to be a surface deposit from an old maltha spring.

Pierce Larkin in 1915 confirmed the presence of oil and gas in shallow water wells, two of which are in NE. ¼ Sec. 16, and found evidence of favorable structure in local dips. On his recommendation a block of acreage was secured by the McMann Oil Company, who sold their holdings to the Magnolia Petroleum Company before the leases were prospected.

SUBSURFACE

Permian.—Interpretation of the subsurface structure is extremely dffiicult, because of great unconformity between the Permian beds and those of the buried hill and because of the lenticular character of the Permian producing horizons. It can at best be only generalized and this generalization has been attempted in constructing two contour maps. One of these maps is on the top of the producing horizon (Fig. 2). In constructing it the gas was used as a marker near the top of the structure and oil on the flanks. The other map shows the unconformable contact of the Permian with the buried hill of older sediments (Fig. 3).

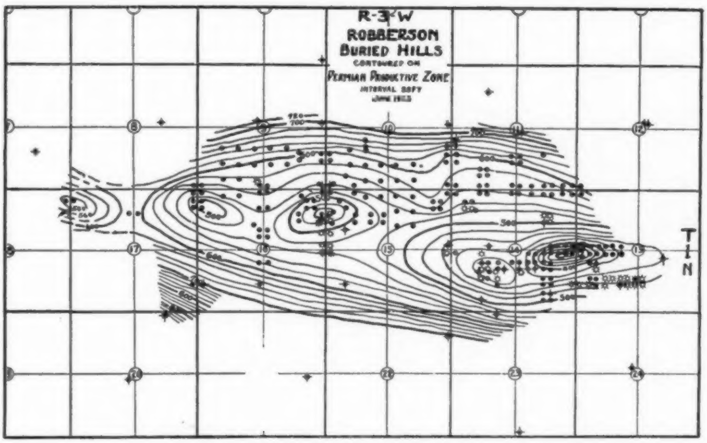


FIG. 2.—Subsurface contours on Permian productive horizon

Contours on the Permian productive zone (Fig. 2) show a number of domes or highs which show remarkable similarity to the peaks of the Robberson Hills. Two of these domes, namely, the one in Secs. 13 and 14, and Secs. 15–16, lie directly over peaks in the older sediments. The other domes in the Permian have not been sufficiently prospected to determine the presence of unconformable sediments underneath. The absence of any evidence of the productive zone in deep wells to the northeast, east, or southeast of the field is notable.

Pre-Permian.—Contours in Figure 3 must not be construed to represent the attitude of the strata composing the "Robberson Hills." They do perhaps represent the approximate topography of these peaks at the time of their erosion and subsequent covering by Permian sediments. Three peaks are shown; one in Secs. 13–14 is well defined, three wells have penetrated the peak in 15–16, and only one well has been drilled in Sec. 19; samples from this well show clearly the presence of another buried peak. A broad saddle connects the first two mentioned peaks while a sharp syncline is present between the first and last peaks described.

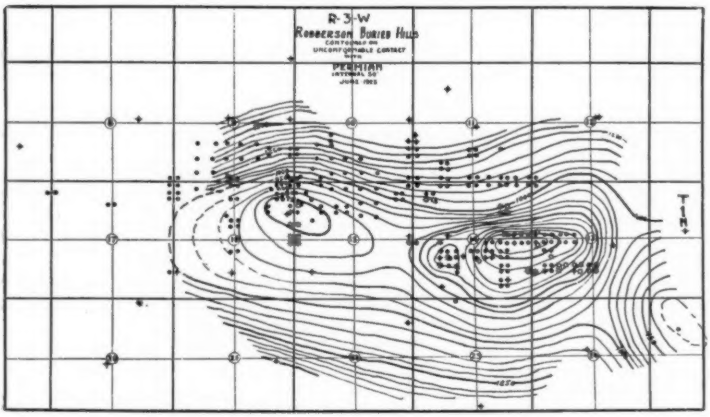


FIG. 3.—Subsurface contours on the "Robberson Hills"

Figure 4 gives in diagrammatic form the attitude of the strata composing the hills, as indicated by wells drilled into it, to varying depths. This shows why offset wells encounter entirely different beds when drilled to the same depth. It likewise explains why dry holes may offset good producers since the pay zone may be entirely absent in one of two adjacent wells. The actual dip as indicated in offset wells is as high as 30°. All the beds of the buried hills so far identified, dip north, making the ridge a monoclinal structure. Sufficient prospecting has not been done to prove the absence of south dipping beds. However, if the producing stratum

is present dipping south it will of necessity be south of and separated by a strip of dry holes from the present producing area.

Drilling thus far has outlined clearly one buried peak lying with its axis about the center line of Secs. 13 and 14 (Fig. 5); a similar peak, though much lower and so far only touched in three wells, occurs in Secs. 15 and 16. A third apparent peak has been encountered by the Texas and Pacific Coal and Oil Company's J. Franklin No. 1, NW. $\frac{1}{4}$ Sec. 19, T. 1 N., R. 2 W., but the outline of this hill cannot be predicted. The present wells show the highest

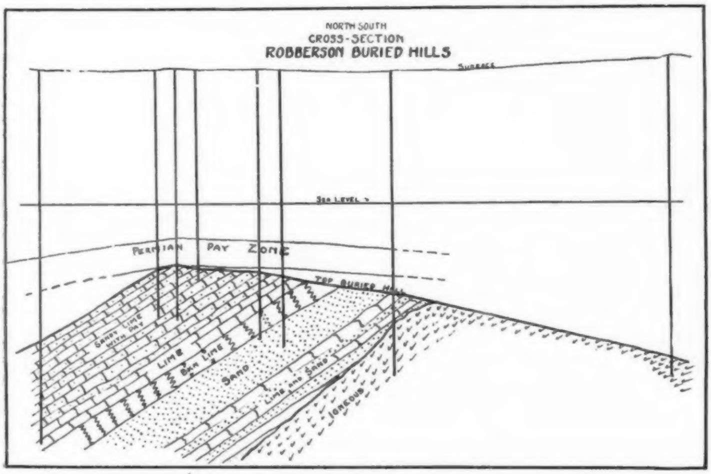


FIG. 4.—Diagrammatic cross section showing altitude of beds in the buried hills

point of the peak in Secs. 13–14 to be −410 feet, that in Sec. 19, T. 1 N., R. 2 W. 612 feet, and the one in Secs. 15–16 to be −705. The lowest point encountered on the Robberson Hills is Magnolia's Hodges No. 1, SE. Cor. NW. $\frac{1}{4}$ Sec. 9, T. 1 N., R. 3 W., at −1,674, giving a maximum relief of 1,254 feet.

ORIGIN

The hypotheses of differential settling and tangential compression must be combined to account for the structure in the overlying Permian of the Robberson field. By the use of Black-

welder's[1] assumptions for the amount of condensation in shale, lime, and sand, the average settling of the Permian strata is 1.3 per cent. The maximum relief at present shown is 1,264 feet and this is sufficient to produce a structural feature of 164 feet. Figure 2 shows more than 200 feet of closure and the additional folding may be due to tangential compression in the buried hill sediments since they are an extension of the same beds which compose the Arbuckles and being in line with the major axis would be subject to all the movement taken place in the Arbuckles, since Permian times.

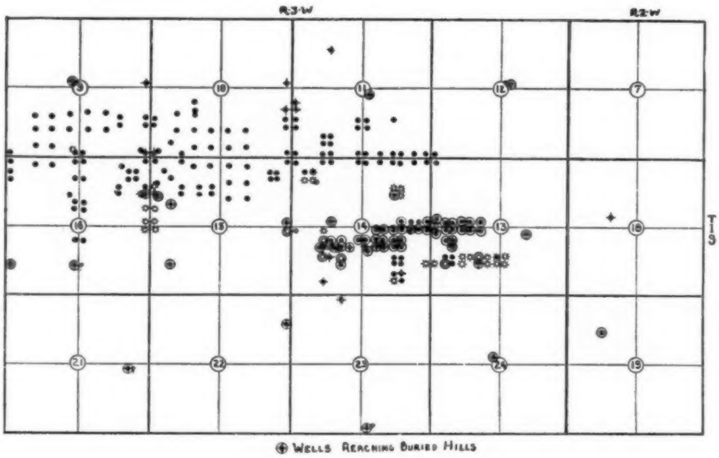


FIG. 5.—Wells penetrating "buried hills"

Although the Robberson Buried Hills are composed of both igneous and sedimentary rocks, the high peaks are composed of sedimentary rocks. These have been reflected in the structure of the overlying Permian. This structure differs from other buried hills in southern Oklahoma such as Healdton and Crinerville, in that the production is in Permian and Ordovician, instead of Pennsylvanian and Ordovician.

[1] Eliot Blackwelder, "Origin of Central Kansas Oil Domes," *Bull. Am. Assn. Petr. Geol.*, Vol. IV, No. 1, 1920.

PRODUCING "SANDS"

Permian.—Samples from the Newberry sand with but few exceptions are shown to be loosely consolidated conglomerates containing some fragments as large as a hazelnut, and consisting of chert, limestone, crystalline quartz, and feldspar. Some fragments are angular and others well rounded; in general the lime is best rounded while the chert and quartz are angular and the feldspar only slightly rounded. The condition of these particles indicates short transportation from an area undergoing rapid weathering. The upper members of this series may be equivalent to the gas sands which occur on top of the buried hill, as one well, the Homaokla No. 1 Hervey produced 20,000,000 gas and 60 barrels of oil and is far down the slope of the buried hill. All other wells producing oil from these sands do not have sufficient gas to make them flow for more than a few days. Two members near the top of the Newberry series have a rather constant interval for local areas but the interval changes greatly over the field. The discovery well produced from the upper sand, but many later wells found this sand barren and were drilled to the lower.

In other parts of the field only one sand is productive and it is considered to be the lower sand, as the second sand is more persistent and is a better producer than the first. Below these two sands numerous shows of oil and gas are found, but in these only one commercial producer, Hart Ringer No. 4 SE. Cor. SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ Sec. 11, has been completed. Deeper drilling in producing areas will possibly encounter this sand over much of the present developed territory.

Pre-Permian.—The big pay horizon in the buried hill ranges from 4 to 402 feet below the base of the Permian. The biggest wells seem to find their oil only a short depth in the hill, as Nelson Brothers' No. 5 Jones was drilled 22 feet into the limestone, Humble & Powell No. 1, 4 feet in, and Texas and Pacific Pearce No. 2, 10 feet in. Depth of production is also variable. For example, the Humble's G. Powell No. 1 produced 1,000 barrels from 882 feet below sea level, while the No. 5 G. Powell, one-fourth mile west, produces 8,000 barrels daily from 420 feet below sea level. No positive proof can be shown that all of the producers in the

buried hill come from one stratum, in fact, several shows of oil are found at varying depths in the buried hill. However, it is assumed that the gusher production must all be in approximately the same zone and have a common source for the oil and gas. A significant fact is that no offset to either of the two biggest wells in the field made more than 150 barrels initial production, although in some cases the offset was producing from approximately the same or a greater depth before the "gusher" well came in. Where samples have been secured from producing wells, in the buried hill, they show wide variation. The Humble-Gertie Powell No. 5 NW. ¼ NE. ¼ SE. ¼ Sec. 13, is apparently in sand composed of medium-sized subangular to rounded grains. The same company's G. Powell No. 1, NE. ¼ NE. ¼ SE. ¼ Sec. 13, produces from a very fine-grained almost quartzitic sandstone very closely resembling limestone. A similar sample comes from Mays & Company's No. 4 Wyatt, SE. Cor. SW. ¼ NW. ¼ Sec. 14. The last samples from Nelson Brothers' Newberry No. 5 before it blew in show a slightly crystalline limestone, very porous and carrying pyrite crystals.

PRODUCTION

OIL

Up to July 1, 1923, a total of 174 productive oil wells were completed. The average initial production of the wells in the Permian sand was about 50 barrels per day, although several made as much as 250 barrels. The wells drilled into the buried hill yielded from 15 barrels to 8,000 barrels. A tabulation of the larger wells, all in the buried hills, with their initial productions follows:

Well	Initial Production	
	Oil	Gas
	Barrels	Cubic Feet
Nelson Bros. Jones No. 5, NE. SW. Sec. 14	8,000	25,000,000
Humble G. Powell No. 5, NW. NE. SE. Sec. 14	8,000	20,000,000
Humble G. Powell No. 1, NE. NE. SE. Sec. 14	1,000	....
Texas and Pacific Pearce No. 2, NW. NE. SW. Sec. 13	1,100	....
Texas and Pacific Pearce No. 1, NE. NE. SW. Sec. 13	800	....
Texas and Pacific R. Newberry No. 2 A 2-NE. NW. SW. Sec. 13	400	....

The oil produced is a black mixed base crude varying in gravity from 25° to 33° Baume, the average being 28°. The better grade

of oil is found in the sediments of the buried peaks and becomes progressively lower in the Permian at greater distances from the axis of the peaks. Due to the large number of small operators with only limited production and inadequate facilities for conserving the lighter constituents, most of the oil sold is below 28° Baume, the gravity being taken at the time the tank is run to the pipeline. The analyses show gasoline content at 302° F. ranging from 11.1 per cent to 15.8 per cent, kerosene at 302°–572° F. from 21–28 per cent, residuum at 572° F. 67.3–67.9 per cent, and gasoline and naphtha distilling below 302° F. from 15.5 per cent to 21.4 per cent.

The oil from the Permian is notably free from water as many of the sands have been entirely penetrated without finding water. The oil from the producing horizon of the buried peaks shows water and emulsion, and is generally treated before it is put into the pipeline. One well, Nelson Brothers Jones No. 5 Sec. 14, carried 25 per cent of water and emulsion. The emulsion was extremely difficult to break, and a large quantity of the oil from this well was never put in pipeline condition. The water is separated by treating with chemicals, while the only successful method of handling the emulsion is by centrifugal separators.

GAS

Although gas was the original product of this field, no effort has been made to develop a large gas supply. The gas from the first wells was used exclusively for fuel and it was not until January, 1923, that an adequate pipeline was connected with the field. A great many of the present gas wells in the field are the result of plugging back from failure to find oil at lower depths.

The open flow capacity from 29 completed gas wells in January, 1923, was 249, 000,000 cubic feet, an average of more than 8,000,000 cubic feet per well. This includes some wells over two years old. The average initial production for the field is around 15,000,000 cubic feet but several wells have made more than 35,000,000. The rock pressure varies from 275 to 600 pounds, the average being 350 pounds. The gas is dry and usually free from water. Samples taken from various wells in the field show from .6 to .8 gallon of gasoline per 1,000 cubic feet, which is too small to be of

commercial value. Very little casing-head gas is made by the oil wells and no effort is made to utilize the supply.

DECLINE CURVES

The chart (Fig. 6) shows the family decline curve based on average daily production per month, for wells in the uppermost

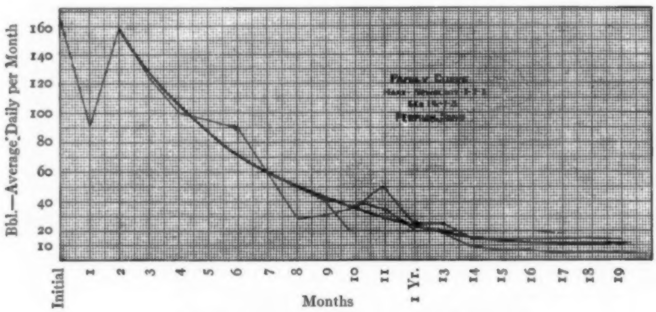


FIG. 6.—Decline curve on Permian "sand"

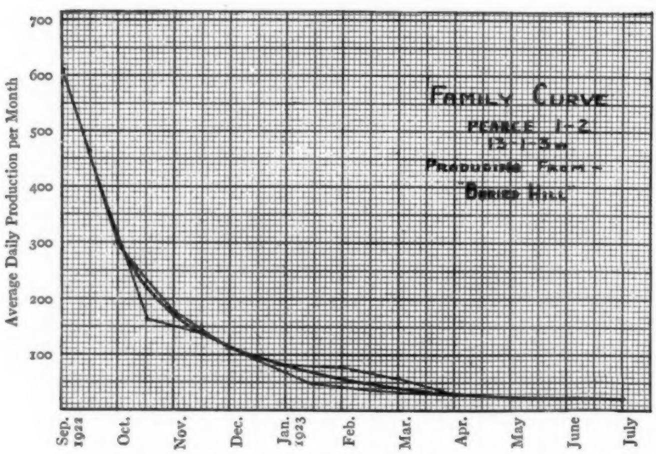
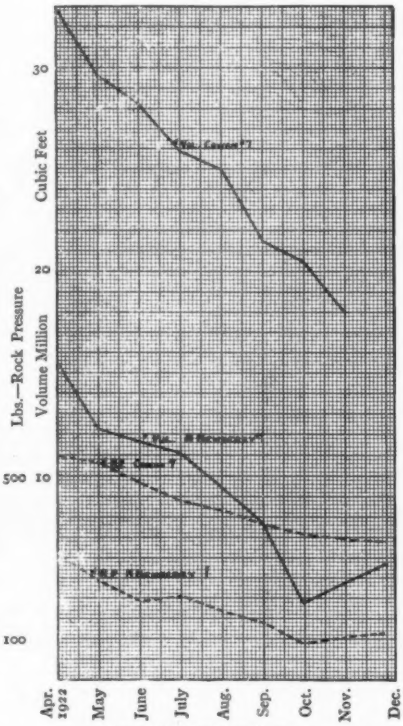


FIG. 7.—Decline curve on Buried Hills production

of the Newberry sands. This shows a rapid but very regular decline with very little flattening until the wells are more than

one year old. Since the productive sands are very coarse and porous these wells cannot be expected to have a long life. They will eventually be exhausted by the extraction of all available oil in the sands and not by encroachment of water.

Figure 7 gives the family decline curve in average daily production per month for wells producing in the older sediments. These wells have far greater initial production and the curves differ radically from those in Figure 6, since they have a sharp decline at beginning, followed by flattening of the curve after seven months of production. This type of curve indicates water pressure. Pearce No. 2, NW. ¼ NE. ¼ SW. ¼ Sec. 13, showed water one month after completion. All of the large wells are near the apex of the buried peak in Secs. 13 and 14. They are short lived, flowing from two to three weeks and declining rapidly as the gas pressure decreases. For example, Humble's G. Powell No. 5 came in May 1923, for 8,000 barrels and on July 1 it was pumping 50 barrels.



Normal Gas Decline—Cowan 7
Effect of "Pulling"—N Newberry 1

FIG. 8.—Decline curve on gas wells

Figure 8 shows the decline in volume and rock pressure of gas wells in the Mauldin beds of Permian age. Cowan No. 7, NW. ¼ SW. ¼ NW. ¼ Sec. 15, was allowed to produce normally while the effect of "pulling" a well caused by the excessive amount of gas used for firing boilers is shown in the curve of N. Newberry

No. 1, SE. ¼ NW. ¼ SW. ¼ Sec. 14. During September and October a decline of the latter well was brought forward far below normal. Later the volume and rock pressure rose after the well was shut in several weeks.

Figure 9 shows the average daily production of the field per month, the average daily production per well per month, and the number of wells producing for the month. Several high points are shown in the average daily production per well. These in every

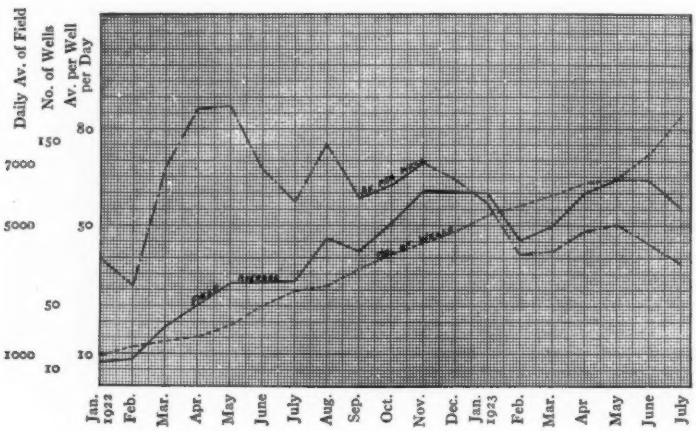


FIG. 9.—Chart showing number of wells and total daily production for field, and average daily production per well.

case can be accounted for by the bringing in of a gusher well with high initial production. The peak in average daily production was reached in May, 1923, and held during June, 1923. A rather marked decline began in July and may be expected to continue.

RELATION OF STRUCTURE TO PRODUCTION

Oil in the Permian occurs well down the north flank of the peak in Secs. 13 and 14 while in Secs. 15 and 16 it occurs on top of the buried hill. The Permian productive zone does not appear to be present on the south flank of the Robberson Hills, for although a few producing wells have been drilled on this flank, they are small

producers and are thickly interspersed with dry holes. Production on the north flank appears to be limited by pinching out of the gravel beds, since dry holes in this area record no "sand" at the regular pay horizon. This would indicate a very lenticular character for the producing beds.

Producing gas wells are all in the Permian, although a large amount of gas is produced with the oil in gusher wells. The gas pay is likewise lenticular, but occurs on both flanks of the Robberson Hills extending about half way down the side of the structure. Good production is found in the saddle between the peak in Secs. 13 and 14 and the peak in Secs. 15 and 16.

Two of the three peaks shown in Figure 3 produce oil. All the large wells are located near the apex of the highest peak. A small well has been completed in Sec. 19, T. 1 N., R. 2 W., but only shows of oil and gas have been encountered in Secs. 15 and 16. Unless further drilling proves the peak in Sec. 19 to be higher than the present well shows, no large production may be expected from this peak.

ORIGIN OF THE OIL AND GAS

There are two hypotheses for the origin of the oil in this field.

The petroleum may have originated in the sediments of the buried hills and migrated from there into the course sands of the Permian. This would require the oil to have been formed after Permian times, or else to have been effectively sealed at the time of erosion and subsequent covering. The latter assumption would necessitate an alteration of the bituminous material in the sealed unconformity since being covered. This could be accomplished by convection currents of gas which gradually dissolve the sealed unconformity allowing oil and gas to enter the coarse gravel and sand lapping up on and covering the buried hill.

The oil and gas may have originated in the sediments surrounding the buried hills and migrated into the upturned sediments. Since the presence of Pennsylvanian strata in deep wells drilled both on and off structure is doubtful, the oil must have originated in the Permian. Numerous beds of rich brown shale occur above and through the Newberry sand series. These seem to offer the most favorable evidence for oil formation.

Whatever may be the origin of the oil, it is certain that the oil both in the Permian and the buried hills is from a common source, since analyses show them to be identical in character.

METHODS OF DEVELOPMENT

WELL SPACING

The early wells in the field were all drilled as line locations, 150 feet being the usual distance; but as the field progressed and many small tracts were developed wells were spaced in an irregular manner, according to the individual idea of the operator. The closest spacing is around gusher wells, where as many as four wells are drilled on 10 acres. In the last six months, the major operating companies have drilled only one well in the center of each 10 acres, which spacing is sufficiently close to drain the coarse "sands" of the Permian. Wells drilled into the buried hills can be spaced closer since the difference horizontally of 100 feet may mean the difference between a small well and a gusher.

DRILLING SYSTEMS

Rotary tools are now used exclusively to drill through the upper Permian beds. The common practice is to set a string of $8\frac{1}{4}$-inch casing on top of what is thought to be a producing horizon. The hole is then finished with either standard tools or a star drilling rig, setting a liner from the bottom of the $8\frac{1}{4}$-inch casing to the top of the producing horizon.

All gas wells are drilled in with rotary tools. After cementing the $8\frac{1}{4}$-inch casing, the sand is penetrated and as the mud is thinned the wells usually "clean" themselves.

Only one string of casing is necessary in drilling the average well. When deeper tests are made, a string of $6\frac{5}{8}$-inch is carried down the hole to shut off water horizons passed through.

PIPELINE FACILITIES

There are two pipelines which run oil from the Robberson pool. Magnolia Petroleum Company has a 6-inch line to Healdton which has a capacity of 6,000 barrels per day. It began operation January 1, 1922, and carries most of the production from the field. The Texas and Pacific Coal and Oil Company has a 4-inch line to their

refinery at Wynnewood, capacity 5,000 barrels. This line was built primarily for transporting their own production but they have recently been taking oil from other operators. Aside from the stock tanks on the leases the only storage is two 55,000-barrel tanks used by the Texas and Pacific Coal and Oil Company in connection with their pipeline.

The Lone Star Gas Company is the only purchaser of natural gas. They have a 12-inch delivery line connecting with a 16-inch trunk line at Dixie, Oklahoma. The pumping plant has six 160 h.p. engines with a total daily capacity of 15,000,000 cubic feet. This plant has been operating since January 4, 1923. The amount of gas taken per day varies with the needs of the purchaser. The output in January, 1923, was 8,000,000 cubic feet per day, and this figure is much reduced during the summer months. The producer is paid 6 cents per thousand cubic feet and the amount taken is prorated among all the operators.

FUTURE OF THE FIELD

The field at present (July, 1923) has 174 oil wells, 33 gas wells, 30 dry holes, 17 drilling wells, and 5 wells shut down. The field is approximately 6 miles from east to west and varies from ¼ to 1 mile in width. Very few leases have been entirely drilled, and a large amount of proven territory on the flanks of the buried hills still remains to be drilled. Much deeper drilling is in prospect, after the present producing sands are exhausted, since it is probable that lower oil horizons are to be found in the Permian. The Texas and Pacific Coal and Oil Company No. 1 Franklin, in the NW. ¼ Sec. 19, T. 1 N., R. 2 W., possibly opens up an entirely new territory. Although this is only a small producer, the Permian sand surrounding the buried hill will probably be productive. The well of Wallace, Murphy, et al., in the NW. ¼ Sec. 18, T. 1 N., R. 3 W., which is preparing to standardize at this writing is of interest since it is ¾ mile west of production and will prove much new territory should it be productive. A further possibility for oil is indicated by the monoclinal structure of the Robberson Hills. Assuming that this is a northwest extension of the Arbuckles, production may be found in a great semicircle, of which the present

field is only a part of the north side. Where other islands were present in a Permian sea of sufficient height to cause reflection in the overlying strata, new oil fields may be developed.

The low gravity of the oil produced and the small initial production of the majority of the wells in this field have made development slow. The greater part of the acreage is held by two large producing companies who will develop as they feel the need for new production. For this reason the field perhaps will never reach a high daily production but it will continue to be productive for several years.

THE BELLEVUE OIL FIELD, LOUISIANA

E. HOLMAN AND R. B. CAMPBELL
Shreveport, Louisiana

INTRODUCTION

The Bellevue field is located in Township 19 North, Range 11 West, Bossier Parish, Louisiana, about eighteen miles northeast of Shreveport. It takes its name from the town of Bellevue, former parish seat of Bossier Parish. The field is five miles north of the town of Princeton on the Louisiana and Arkansas Railroad.

Though in 1905 this area was mapped by Veatch[1] as a Tertiary inlier in Quaternary sediments, not until 1917 was there any systematic exploration of the structure. At this time the Standard Oil Company drilled their Heilperin No. 1 in sec. 30, T. 20 N., R. 11 W. (Fig. 1). This well encountered shows of oil in the Nacatoch at 1,059 feet and again in the Woodbine between 2,464 and 2,521 feet. It was finally abandoned at a depth of 3,046 feet after finding salt water. In 1919 Mr. R. O. Roy, an independent operator, drilled Pease No. 1 (Sec. 26, T. 19 S., R. 12 W.), a failure at 2,474 feet, though a good show of gas with some oil was found in the Nacatoch at 920 feet. There was also some oil with the salt water at 2,454–74 in the Woodbine, where the well was abandoned. Shortly after this failure Mr. Roy drilled his Wyche No. 1 (Sec. 14, T. 19 S., R. 12 W.), which also was abandoned at 2,645 feet. A show of gas accompanied by much salt water and a little oil, was reported in the Nacatoch at 900 feet in this test. Mr. Roy's next attempt, Smith No. 1 (Sec. 7, T. 19 S., R. 11 W.), was completed as a twelve-barrel pumper at 2,173 feet in the Woodbine, producing a high grade oil. Distillation of a sample of the oil, 38.2 gravity crude showed 34.5 per cent gasoline, gravity 59.2; 22 per cent kerosene, gravity 44.1; and 43 per cent fuel, gravity 19.2. This crude compares very

[1] A. C. Veatch, "Underground Water Resources of South Arkansas and North Louisiana," *U. S. Geol. Survey*, Prof. Paper 46, 1906.

favorably with that from Homer. The well was not a commercial producer but it indicated the possibilities of a pool of high grade oil at this horizon on the Bellevue structure.

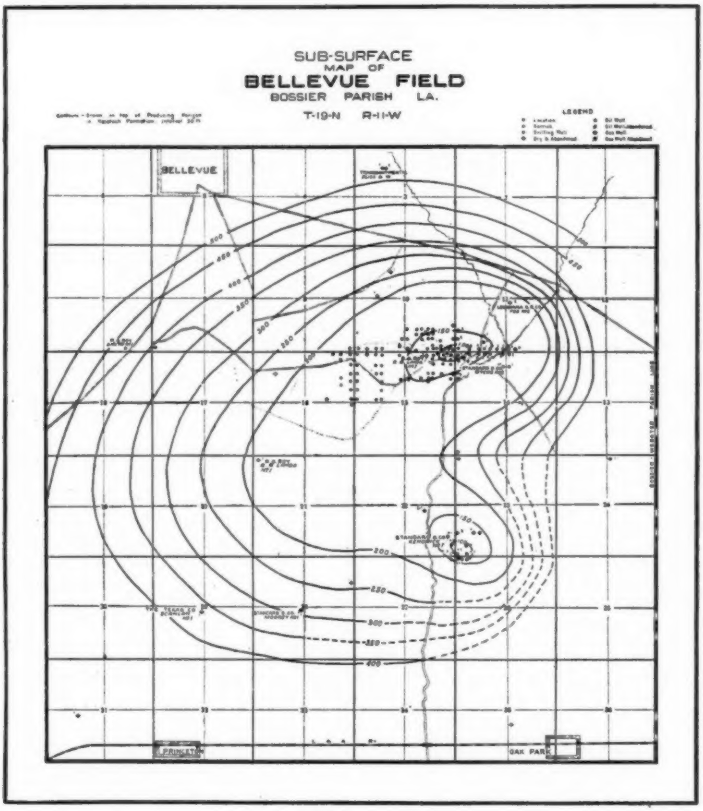


Fig. 1

In the following year five more deep tests were drilled without success around this producing well. The deepest of these was the Scandland No. 1 of the Texas Company, with a depth of 4,052 feet and finishing in the Lower Cretaceous. While these deep tests

were being made, Mr. Roy and Mr. J. Y. Snyder, geologist, were exploring the area to the east, by making shallow tests to the Nacatoch sand. After about a dozen of these tests, oil in commercial quantities was discovered on November 13, 1921, in the Railroad Lands No. 7 in Sec. 15, T. 19 S., R. 11 W., at 398 feet (182 feet below sea level). In this way was developed the very remarkable shallow Bellevue pool which probably contains the largest wells ever brought in at this small depth.

GENERAL GEOLOGY

The Bellevue area is a nearly featureless plain about 215 feet above sea level, traversed by a small stream flowing from northeast to southwest. In the rainy season the field is a swamp. The entire area is heavily timbered except for a couple of open prairies.

The surface formation above the shallow oil pool consists of a gray sandy clay apparently Quaternary in age. However, boulders of Wilcox age are found west and south of the field, and beds of St. Maurice (Lower Claiborne) are recognized a short distance south, east, north, and northwest. Farther in these directions are deposits of Cockfield (Upper Claiborne) and Quaternary deposits. It is possible that the "prairies" to the east, with their blue clay subsurface, represent the crest trace of the structure. Well records demonstrate that the first formation encountered by the bit is probably Midway or Arkadelphia.

The formations penetrated by the drill in the Bellevue field will be described briefly, in order from the surface downward.

Arkadelphia.—This formation, the uppermost of the Upper Cretaceous, consists of dark blue to black gummy shales, though boulders, probably sand concretions, are frequently logged in the lower part of the formation.

Nacatoch formation.—Immediately below the Arkadelphia occurs the Nacatoch formation, a sandy series with medium sized sand grains and some glauconite, the whole more or less consolidated with a calcareous cement. This sand is the gas sand of the Caddo field. Below are some excerpts from logs in the Bellevue field showing the Nacatoch formation as recorded.

R. O. Roy, Railroad Lands No. 10, 15–19–11

350–366, Gumbo
366–368, Gas rock

Standard Oil Co., Louisiana Oil Refg. Corp. Fee No. 4, 11–19–11

279–281, Lime
281–297, Light shale
297–332, Black gumbo
332–332½ Soft oil sand
332½–333, Hard oil sand
333–334, Oil sand, streaks of hard sandstone

Standard Oil Co., Bell No. 3, 16–19–11

350–367, Shale, showing gas
367–380, Broken lime rock, showing oil
380–382, Oil sand and hard lime

Standard Oil Co., Wyche No. 3, 14–19–11

330–333, Sandy streaks of lime
333–338, Soft sand
338–340, Sand and rock, showing oil
340–366, Sand, streaks of lime
366–369, Sand
369–380, White sand
380–385, Gumbo
385–392, Sand
392–398, Sand rock
398–400, Sand

Standard Oil Co., Wyche No. 4, 14–19–11

274–277, Hard lime
277–282, Hard rock
282–283, Sand and rock
283–287, Hard rock
287–288, Sand and rock
288–290, Hard rock
290–291, Oil sand

Louisiana Oil Refg. Corp. Bodcau Fee, A–11, 15–19–11

228–242, Lime and chalk
242–257, Shale
257–307, Lime and chalk
307–312, Cap rock
312–321, Broken sandy lime
321–325, Sand

Louisiana Oil Refg. Corp. Bodcau Fee, B-4, 11-19-11

246-340, White shale and chalk
340-349, Gumbo
349-357, Lime cap
357-362, Lime and oil sand
362-367, Oil sand

Standard Oil Co. Bell, No. 1, 16-19-11

389-393, Broken lime
393-395, Shell and lime
395-406, Oil sand

Standard Oil Co., Louisiana Oil Refg. Corp. Fee No. 2, 11-19-11

349-352, Brown oil sand (dry)
352-354, Hard shell
354-355, Oil sand

Chalk series.—Below the Nacatoch the drill encounters a series of marls, chalks, and limestones aggregating about 600 feet in this field. This series is divisible from above downward into the Marlbrook marl, Annona chalk, and Brownstown marl. The Marlbrook marl, as recorded by the driller, seems to vary in thickness, for it is difficult to distinguish by rotary drilling the difference between soft chalk and chalky gumbos. Consequently no definite lines of demarcation can be made between the Marlbrook and the Annona. However, comparison of the logs available shows a probable thickness of about 100 to 150 feet. The Annona chalk, below the Marlbrook, consists mainly of chalk and chalky shale. In estimating the thickness of this formation one meets with the same difficulty as with the associated marls. Its thickness in this field is probably about 250 to 300 feet. The next formation is the Brownstown marl consisting of a calcareous clay with very little sand. The logs usually show gumbo and shale, some sand and boulders. The thickness is 100 to 150 feet.

Eagle Ford series.—Beneath the Chalk series is a succession of sandy shales and clays with occasional streaks of lime, with a thickness of about 500 to 600 feet. In the upper part occurs a sand 50 to 150 feet in thickness, known as the Blossom sand. This sand produces oil and gas on the Sabine uplift, oil at Homer and

Haynesville and gas in the Webster Parish area. It consists of quartzitic sand with grains fairly coarse to fine, angular, subangular or round. Some glauconite is present.

Woodbine.—Below the Eagle Ford is the so-called Woodbine, the basal member of the Upper Cretaceous series, it consists of sand, red shales and gumbos.

Lower Cretaceous.—Below the Woodbine is a series of limestones and shales with a probable thickness of 2,000 feet or more. It is not possible with the well logs available to determine the lines of demarcation, but in the case of the Standard Oil Company, Wyche No. 2, the lower 300 feet of red shales and gumbo probably indicate that the Trinity was penetrated.

STRUCTURE

Mapping of the top of the producing sand shows that the rocks at Bellevue are in the form of an asymmetrical dome with more than 500 feet of closure. To the northeast the beds dip about 1,700 feet in 6 miles, to the southeast a like amount, to the southwest about 900 feet in 9 miles, and to the northwest about 1,000 feet in the same distance. The Bellevue area is thus a dome on the east side of the Sabine uplift, separated from the main uplift by a shallow syncline. The Cretaceous formations on this dome are higher structurally than anywhere else in this territory except in the region of outcrop and around salt domes.

Concerning the origin of the dome two interesting hypotheses are presented. First, it may be noted that this dome is on the main northeast-southwest cross-fold of the Sabine uplift and accordingly may represent the nodal point of folding on that uplift, as the Bethany field apparently is on the west side. Another possibility is that the Bellevue fold is a salt dome. The shape and size of the fold point to this, as well as the fact that it is directly in line with the salt domes on the east side of the Sabine uplift, Kings Saline and Bistineau. Possibly, then, Bellevue is a salt dome along the same line of weakness, but if so the salt core is very deeply buried, for apparently the formations have not suffered the deformation usually found around salt domes.

DEVELOPMENT

On March 1, 1923, Bellevue had an approximate daily production of 6,370 barrels of oil per day and had to this time produced about 1,400,000 barrels of oil. There were 100 producing wells, three gas wells, two wells temporarily abandoned and thirty-two failures in the district.

Shortly after the discovery of the pool, water appeared in large quantities and seemed to indicate the short life of the field. However, production still holds up and is improving. Some wells have had a remarkable record, notably the Humble Oil and Refining Company's Roy-Bliss & Wetherbee No. 2, which came in with eight to ten thousand barrels of fluid of which 4,000 barrels was oil. It is now making about 700 barrels per day flowing on gas. The Gulf Refining Company's Bliss & Wetherbee No. 8, now on air, is producing about 1,000 barrels per day. The discovery well was recently opened after having been closed in for months and is reported to have flowed at the rate of 300 barrels per day. Some wells have behaved very erratically, ceasing to flow or recommencing after having been dead, from the comparatively negligible concussion of the dynamiting of stumps at the surface.

The wells are drilled with both rotary and Armstrong rigs. The cost of drilling a well with the former is about $2,500, and with the latter about $1,650. The cost of production of Bellevue oil is about 26 cents per barrel including treating.

The crude has a gravity of 19.3 Baumé, contains 2.5 per cent gasoline, gravity 63.6; 2.5 per cent naphtha, gravity 54.2; 7.5 per cent kerosene, gravity 43.3; 12.5 per cent gas oil, gravity 33.5; 30 per cent spindle oil, gravity 27.2; 38 per cent lubricating oil, gravity 21.3; 7 per cent loss and coke.

The field is served by two pipe lines. The Standard Oil Company has an 8-inch line to Princeton and the Louisiana Oil Refining Corporation a 6-inch line to a loading rack at Drake. Both Drake and Princeton are on the Louisiana & Arkansas Railroad.

POSSIBILITIES FOR FUTURE PRODUCTION

The production in this field is from the Nacatoch. Three sands below the Nacatoch offer possibilities,—the Blossom, Woodbine

and Trinity. Of these the Blossom seems to be very poorly represented on the top of the dome, but offers some possibilities on the flanks of the structure. The Woodbine seems to offer better possibilities, as it is apparently present throughout the area and has already produced high-grade oil (Roy-Smith well). The Lower Cretaceous offers several favorable horizons in the Trinity series. The gas in the Standard Moorey No. 1 was from the top of the Trinity.

Though several wells have been drilled through nearly all these formations without success, it is probable that these sands will be more regular on the sides of the dome than on the top where the formations have suffered more or less deformation.

SUMMARY

The Bellevue oil field, which has probably the largest wells ever brought in at the shallow depth of 300 feet (only 60 to 100 feet below sea level), is probably on a buried salt dome or the nodal point of transverse folding on the Sabine uplift. On the surface it is marked by the presence of a Wilcox or possibly older inlier surrounded by Claiborne and younger sediments.

The present production, a crude oil of 19.3 gravity, high in lubricating content, is from the Nacatoch formation with possibilities of further production in the Blossom, Woodbine, and Trinity series, all within reach of the drill.

THE NEGLIGIBLE OIL POSSIBILITIES OF WISCONSIN

W. H. TWENHOFEL

INTRODUCTION

During the past several years numerous attempts to develop oil booms in Wisconsin have been made. In some cases promotion for personal profit appears to have been the stimulus, but in most instances the proposed developments seem to have been initiated by sincere, patriotic people, whose aim to develop an oil industry in Wisconsin was not guided by an adequate knowledge or appreciation of the geological conditions which are essential.

It is the purpose of this article to present a brief statement of the oil possibilities of Wisconsin. For data relative to the thickness of the various rock divisions, thanks are due Mr. F. T. Thwaites, who is in charge of the collection and interpretation of well records, one phase of the work of the Wisconsin Geological and Natural History Survey.

At the base of the geologic section in Wisconsin are the pre-Cambrian schists and granites and other types of igneous and metamorphic rocks. Overlying these older rocks are sandstones and sandy shales of upper Cambrian age, and these are succeeded by Ordovician dolomites, shales, and sandstones. Above the Ordovician strata are the Silurian dolomites, and near Lake Michigan is a small area underlain by Devonian shales. Widespread over the surface are glacial drift and other unconsolidated materials of recent origin.

A broad arch with axis trending north and south extends approximately through the center of the state. The axis plunges southward, and the Paleozoic strata thus dip east, south, and west,—in most places at a very gentle angle. The distribution of the formations is shown on the accompanying map (Fig. 1).

PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks underlie the north and north central parts of the state and consist of various types of more or less anamorphosed igneous and sedimentary rocks. Description of

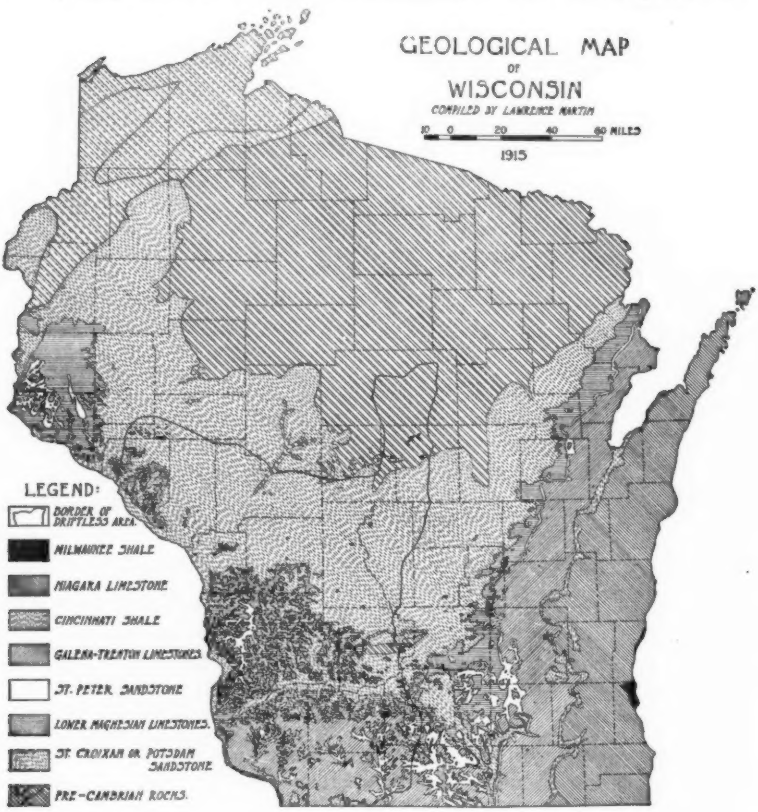


FIG. 1

these is unnecessary, for the occurrence in them of commercial oil and gas is thought impossible. Neither oil nor gas should be expected in those portions of the state where, except for the mantle of glacial drift, these old rocks immediately underlie the surface.

PALEOZOIC SYSTEMS

The Paleozoic is represented in Wisconsin by the Cambrian, Ordovician, Silurian, and Devonian systems, their outcrops being arranged concentrically with respect to the pre-Cambrian rocks of the northern part of the state. The Cambrian and Ordovician appear at the surface in a horseshoe-shaped area in the eastern, southern, and western portions of the state. The Silurian is scantily represented in southern and western Wisconsin, but has a wide distribution in the eastern part of the state. The Devonian rocks occur in a small tract along the shore of Lake Michigan.

Cambrian.—The Cambrian strata consist of sandstones and sandy shales which include one or two members of sandy dolomite. They belong to the St. Croixan or Upper Cambrian, the upper limit of which is taken as the base of the Lower Magnesian dolomites. The total thickness of the Cambrian of Wisconsin varies from about 700 to 1,000 feet, but where erosion has occurred, the remaining thickness is less.

The Cambrian strata contain neither oil nor natural gas. Deep wells have been drilled throughout the area of distribution of these rocks, and in every instance fresh water has been obtained. The strata are dominantly of marine origin, and originally they must have contained some salt water, but fresh water has circulated through the beds for so long a time that all of the salt has been washed out, and with it has gone any oil which may have been present. Moreover, it appears unlikely that organic matter could have been deposited with these sediments in such a way as to preserve the fatty matter from which oil or gas might have been distilled. Hence, as an oil or gas prospect, any portion of Wisconsin immediately underlain by the Cambrian rocks is practically hopeless.

Ordovician.—The rocks of the Ordovician system are largely dolomite, but include some shale and sandstone, and in order upward are subdivided as follows: Lower Magnesian dolomites, St. Peter sandstone, "Trenton" dolomites, the Richmond or Maquoketa shales, and the Neda formation. The Lower Magnesian dolomites are divisible into the Oneota dolomite at the base and the Shakopee dolomite above, the two divisions being 250 feet thick

in some places and separated along Mississippi River by a thin sandstone member known as the New Richmond sandstone. The dolomites are gray to buff in color, and they contain very few fossils other than large dome-shaped masses of algal origin. Chert is abundant in some horizons, and is oolitic in the lower 20 to 30 feet. As this formation is the only one in Wisconsin containing oolitic chert, the division is readily identified by this feature. Small cavities of extremely irregular shape are common, while larger cavities and even caves may be present. The Lower Magnesian dolomites are widely distributed over the western and southwestern parts of the state, where they commonly form the hilltops.

Where the rocks of this division outcrop, they cannot serve as an oil reservoir, for water pressure would force the oil to the surface. Hence, any region where this is the surface rock, is hopeless as a prospect. If any oil had been present in this rock, at other places, which is extremely doubtful, long ago it could have migrated into overlying formations.

The St. Peter sandstone is a clean, well-sorted quartz sandstone, which attains a thickness of 300 feet in some places, and which is separated from the Lower Magnesian dolomites by a marked erosional unconformity. Locally the sandstone is hardened to a quartzite-like rock, and elsewhere it is cemented with iron oxide to form an "iron rock." Over western Wisconsin this sandstone occurs as small patches on the hilltops, whereas in southern Wisconsin it outcrops along the sides of the valleys and caps some of the lower hills. In eastern Wisconsin it comes to the surface along the foot of the escarpment of the Trenton cuesta.

Wherever the St. Peter sandstone has been reached by wells, it contains fresh water. Over the highly dissected southern and southwestern parts of the state it has been cut through in thousands of places, and only fresh water has come from the rock, so that if any oil ever occurred in this formation, it was washed out long ago. Furthermore, the rock contains little or no organic matter, and there is no probability that any significant quantity ever was present. Any oil or gas which might have entered the St. Peter sandstone must have come from another horizon. There seems to have been no adequate source below, and no probable one above, and accord-

ingly it is a safe conclusion that no commercial production of either oil or gas may be expected from this formation.

The "Trenton" dolomites include the rock generally known by that name, the associated Galena dolomites, and still others not yet carefully defined in published descriptions, and vary in thickness from 175 to 450 feet. The strata consist of buff, dark and light gray dolomites, which are generally not so thick-bedded as the Oneota. In eastern Wisconsin, south of Milwaukee, there is a sandstone near the base which is known to the drillers as the stray sand. This reaches a maximum thickness of about 30 feet. The rock contains a great deal of chert in some horizons, none of which is oolitic. Fossils are abundant in some beds. Those which may commonly be found are the "sunflower coral," *Receptaculites;* the small horn coral, *Streptelasma corniculum;* and the small straight-hinged brachiopod, *Orthis tricenaria*.

There is sufficient organic matter in this rock to have given rise to oil and gas, and it is sufficiently porous locally to form a reservoir, but where the rock is not covered by an impervious formation there is no probability that oil or gas is present in paying quantity. This is true for the areas where it outcrops in southwestern and south central Wisconsin. In eastern Wisconsin, where the "Trenton" dips beneath the overlying Richmond shales, an impervious cap is provided, and it is possible that here small pools of oil may be found in the "Trenton." As a matter of fact, small shows of oil are reported in the "Trenton" in two or three of the deep wells which have been drilled to this horizon.

The Richmond-Maquoketa shales consist of interbedded dolomites and dolomitic shales with a thickness of 50 to 540 feet, the greatest thickness being found in Kewaunee County on the southern end of the Green Bay peninsula. In eastern Wisconsin the Richmond comes to the surface at the base of the escarpment of the Niagara cuesta. This belt begins on the Illinois line near Lake Geneva and extends north to Lake Winnebago, where it is exposed along the east shore of the lake. From that point it continues northward to Green Bay City and thence northward at the base of the cliffs along the east side of Green Bay and disappears beneath the waters of Green Bay just before Sturgeon Bay is reached.

There are no horizons in this formation which can serve as reservoirs for any significant accumulations of oil and gas. The importance of the formation with respect to these substances arises from the fact that it forms an impervious cover for the "Trenton." No commercial deposits of oil or gas may be expected west of the north-south belt of its outcrops, to which attention has been called.

The Neda formation has commonly been called the Clinton ore bed, but Savage and Ross discovered Richmond fossils in the ore, on the basis of which it appears that it should be assigned to the Ordovician.[1] The formation consists of oolitic and powdery hematite, hence there is no opportunity here for the occurrence of either oil or gas.

Silurian.—The Silurian strata consist almost wholly of limestones or dolomites, ranging in thickness from 300 to 670 feet. Generally these have been lumped together under the name "Niagara limestone," but in reality they include several formations more or less similar in general characteristics, but differing in detail and in faunas. From the base upward these formations are the Mayville, Byron, Coral, Waukesha, and Racine formations. They consist mainly of gray and light-colored dolomites, which in some horizons carry an abundance of chert. Generally the rock is well bedded in units which vary from a few inches to several feet in thickness but where coralline growths are abundant bedding is essentially lacking. The Silurian dolomites may readily be identified by the local abundance of honeycomb and chain corals. The Niagara limestones form the Green Bay peninsula and thence extend southward along Lake Michigan as a strip about equal to the width of the country between Lake Winnebago and Lake Michigan. The area is a little narrower than that portion of the state where the Trenton is under effective cover.

Because there is no impervious cover over the Niagara limestones, they have no commercial possibilities as an oil reservoir.

Devonian.—The strata of the Devonian system consist of gray calcareous shales with some layers of shaly gray dolomite, and are

[1] T. E. Savage and E. S. Ross, "The age of the Iron Ore of Eastern Wisconsin," *Am. Jour. Sci.*, Vol. XLII, (1916), pp. 187–93.

known as the Milwaukee formation. Apparently they have no important bearing on the occurrence of oil and gas, as their distribution is too limited for them to serve as the impervious cover for the Niagara limestone.

PLEISTOCENE DEPOSITS

The Pleistocene deposits consist of loess, glacial lake deposits, and glacial and fluvio-glacial deposits of variable thickness. In some localities beds of peat have been buried in these materials, and where these have been penetrated by wells the peat or immediately overlying sands have yielded small volumes of natural gas. In some instances these sources have been sufficiently large to supply the needs of a family for a few years, as in the case of several farmhouses near Harvard, Illinois, just south of the Wisconsin-Illinois line. However, this gas was derived from the decomposition of the peat, and though its discovery raised high hopes, the occurrences have little value from a commercial point of view.

SUMMARY

From the foregoing, it is concluded that all of Wisconsin west of the Richmond-Trenton contact of eastern Wisconsin has no possibilities for the commercial production of either oil or gas. East of this contact there are some possibilities, but they are considered extremely poor. The favorable facts are: the "Trenton limestones" locally may be of sufficient porosity to serve as an oil reservoir; sufficient organic matter was buried with the sediments which formed these limestones to produce some oil or gas; and it is not unlikely that local structural conditions occur which favor the accumulation of oil or gas. Unfavorable facts are: not one of the many wells which have been drilled to the "Trenton" has ever encountered anything other than mere oil shows, and most of them have encountered only water; and the country is so heavily drift-covered that it is extremely difficult and commonly impossible to locate the local structures which are responsible for accumulation. The fact that no commercial production has been found in any one of the numerous wells which have been drilled leads the writer to believe that if any large quantities of oil ever accumulated in this

formation they have been washed out. If any such bodies still remain, the pools almost necessarily must be small, and the heavy cover of drift over most of the state makes a discovery very difficult. The conditions are not such that careful, scientific work is likely to yield important results, and they are such that with existing information a conscientious geologist ought not to recommend drilling in Wisconsin for the purpose of obtaining oil.

SOME IDEAS REGARDING OIL ACCUMULATION IN THE ROCKY MOUNTAIN REGION

T. S. HARRISON
Denver, Colorado

Nature's methods in the manufacture and accumulation of petroleum seem to the writer not to have been confined to a single process or series of processes. Heat and time, for example, are doubtless important factors in the changing of organic matter to petroleum products. The possible combinations of the various agencies are innumerable, and accordingly the petroleum combinations derived from any given organic shale may be without number. The amount and character of overburden affect the amount of heat and its conservation. One may reasonably imagine that deep within the earth processes analogous to those of the pressure still may be active. Heat sufficient to increase the carbon ratio beyond the danger point may be generated and yet, because the evaporated gases cannot escape, redistillation may create a commercial product. A light oil, supposed to be the result of filtration through shales, may in fact be a product of cracking.

Faults and fissures, which usually are associated with the folding of rock strata, are most important phenomena in connection with oil and gas accumulation. Indeed, the writer has come to believe them necessary, for without faults gas may not be displaced by oil. In sharp folds the oil, if not in the crest of the structure, may be beyond drilling depth, but faults often furnish avenues up which petroleum may migrate to shallower sand beds. In the absence of sands it may reach the surface and be lost. If fissures are open, the migrating oil may retain its original condition; if minute, some fractionation will take place, heavier parts being left behind.

In connection with a study of the White River dome, Rio Blanco County, Colorado, the writer became interested in some remarkably saturated sands of the upper Wasatch (Eocene). Gas had been developed in sands about 2,000 feet below the top of the Wasatch,

the wells having a capacity of two to four million feet, while one well showed a little oil. Heavily oil-saturated sands, near the top of the Wasatch, flanked the dome. The Lewis marine shale (Cretaceous), which occurs between the Mesaverde below and the Wasatch above, both of fresh water origin, is locally missing. Thin beds of oil shales, similar to those found in the Green River formation which once were spread over the dome, are associated with these saturated sands. Contrary to expectation, analysis of the oil and gas from the well and of the saturated sand indicated no analogy between them. The Smith-Emery Company reported the gas to be 100 per cent methane—the first sample of pure methane they had ever received. Dr. Albert Lowe, of Denver, reported no similarity between the two oils, for with similar laboratory methods and conditions he obtained the following results.

	Oil from Sand	Oil from Well
	Per Cent	Per Cent
Gasoline	12.7	5.2
Kerosene	20.7	50
Heavy oils	50	43.1
Coke	16.6	1.7
	100	100

The oil recovered from the sand was at the rate of 12 gallons to the ton. The well oil before being heated gave no odor. It may have been a coal tar product, since the Wasatch locally contains carbonaceous shale, while, similarly, the methane gas may have been a product of an old Wasatch swamp and not an associate of petroleum.

It may be noted that the saturated sands were high in gasoline, notwithstanding the fact that the samples were taken from the surface. Several analyses of similar sands from other parts of the oil shale region, which have subsequently come to the writer's attention, showed much larger percentages of gasoline and kerosene. With little doubt the oil originated in the Green River and Wasatch oil shales, which contain quantities of organic material which has been called kerogen.[1] From it, upon application of heat, oil

[1] Cunningham Craig, *Jour. Inst. Petrol. Tech.*, June, 1916, Vol. II, No. 8.

products are obtained, which, because of variation in physical conditions associated with the heating, yields products which are variable in character and amount.

According to Winchester,[1] fissures containing a variety of solid hydrocarbons, notably gilsonite, elaterite, albertite, tabbyite, etc., here and there traverse the Green River shales. Several of these veins have been profitably worked. Winchester also reports west of Petrolite Hills,[2] in northwestern Colorado, a fracture zone cutting the Green River formation, filled with a very light yellowish-brown hydrocarbon (specific gravity 1.06) which does not answer the description of any of the ordinary asphaltites.

Recently the Ute Petroleum Company, drilling in a much faulted and folded portion of the Uinta Basin, eastern Utah, in a series above the Green River oil shales, "continuously" found showings of oil, but no commercial accumulation. At one point a rubbery, residuary, asphaltic material was encountered.

At Hill Creek, Sec. 32, T. 42 S., R. 19 E., also in the Uinta Basin, the Utah Oil Company, drilling on a local dome, found oil in several sands but all contained water. The upper sands of the Wasatch are exposed and show oil saturation. This well started too low in the series to be a proper test of the oil possibilities in structures associated with the oil shales, while the Ute Company well was drilled in beds too far above the main oil shale body.

In high hills west of the road, near Piceance Creek between Rifle and Meeker, Rio Blanco County, Colorado, is exposed a series of upper Wasatch sands and shales, aggregating fully 800 feet, in which all the sands are highly saturated. So saturated is the sand that it is tough. One may drive a hole through a fragment of it without its being fractured, but application of heat liberating the oil permits the sand grains to fall apart. A well drilled some years ago back of the outcrop pierced the series and found only "showings" of oil. Unlike some California experience, the oil has not such residuary character that it seals the sand at outcrop and it is high in kerosene and gasoline. Under the circumstances the writer cannot account for their presence. Is it possible that the

[1] Dean E. Winchester, "Oil Shale of Uinta Basin, Utah," *U. S. Geol. Survey*, Bull. 691, p. 49, 1918.

[2] *Ibid.*

oil is yet in a potential state—the gasoline and kerosene not fully developed?

In several instances oil has been found in fracture zones or in sandy layers of shales. Movement may have supplied the necessary heat to distill the oil from the shales and open fractures, the reservoirs for its accumulation. At both Florence and Boulder, Colorado, the oil is found in shale fracture zones, not in sands. It may be suggested that in these instances no large gathering area was possible. It seems probable that oil may have been distilled largely from organic shales immediately adjacent to a movement; that remote from an area of movement the shales may be practically in their primary state. It is also suggested the the amount of oil formed is proportional to the heat generated. Winchester states[1] that a small amount of free oil is found in joints of the undisturbed oil shales. This distillation may be largely the result of heat generated by weight of the rock overburden.

At Spring Valley, Uinta County, Wyoming, oil is found in the Aspen shales (Mowry horizon of the Benton) on the west flank of the Meridian anticline. The region is greatly faulted and folded. At Rangely, in northwestern Colorado, oil is found in fractures in Pierre shales. In the Plunkett field, Fremont County, Wyoming, on the northward plunge of the greatly faulted and sharply folded Popo Agie anticline, oil is found in the Mowry shales. This is also true near Bonanza Springs, Bonanza anticline, Big Horn County, Wyoming. At the outcrop of the Mowry on this sharply folded structure, oil seeps from over 100 feet of beds. Adjacent sands, in all these fields, are water-bearing and without doubt the shales in contact with the sands also contain water. Washburne[2] in his paper on the Florence field has discussed very convincingly the influence of water in the shales on the concentration of oil in fissures.

The Mowry shales have been suggested as the source of the oil of the Frontier sand series, and this origin the writer is inclined to accept in part. The whole series of shales below the Frontier and above the Dakota is highly bituminous. The Frontier sands are

[1] *Op. cit.*

[2] Chester W. Washburne, "Florence Oil Field," *U. S. Geol. Survey*, Bull. 381-d, 1908.

the most important producers of Salt Creek, of Big Muddy, of Grass Creek, of Elk Basin, etc. The Mowry carries fish scales and fish bones everywhere in Wyoming. It has been suggested that the Carlile, Niobrara and Pierre shales, above the Frontier series, may be sources of oil found in those shales. At Salt Creek the dome is severely faulted. On the surface paraffine is found in calcite, lining the fissures, and at many localities in the field are oil seepages. Frequently drilling wells are filled with oil from the grass roots downward; several have been known to flow from the shales, when gas pockets were encountered. The fact that the oil so found is similar to the oil of the sand series suggests the origin. While not presenting a clear case at Salt Creek, because of the residuary character of Shannon oil, it is probable that we have one at Big Muddy.

At Big Muddy, in Natrona County, the principal oil is produced from the Frontier, here a single sand. In the zone of fracture, the so-called Shannon sand, 2,000 feet above the Frontier, has produced some oil—often oil and water. At high points on the dome, it has contained only water. The oil found was of similar character to the Frontier. It is suggested that the Shannon was first full of water, but that oil migrating upward through open fissures accumulated in it, displacing the water. At Big Muddy one feels safer in placing the point of primary accumulation in the Frontier. The writer believes the upper oils at Salt Creek also first accumulated in the Frontier series.

At Pilot Butte, Fremont County, Wyoming, oil was produced in a fracture zone from shales above the Frontier while a test found only water in the sand series. The oil may have been distilled from shales adjacent to its present position; it may have had its source in the Frontier and have been driven upward by the waters, completely depleting the sands. There is an analogy at Teapot.

One would suppose that when the oil had been completely driven from the sand, water would follow. No water was noted in the shales by the drillers at Pilot Butte. However, the writer agrees with Washburne, shales may be partially water saturated, yet that saturation may not be noticeable to the driller.[1]

[1] *Ibid.*

In our Cretaceous fields the fissures are often filled with calcite. At Salt Creek the calcite often contains paraffine, indicating that free oil once passed that way. The writer does not believe that these fissures were filled with water bearing calcite, but suggests that the calcite was deposited by a process of sweating from the fissure walls, even while the fissures may have been filled with oil. Only a water super-saturation of the shales would be noticeable to the driller.

Recently word has been received that the First Wall Creek sand at Teapot contains water. Doubtless oil accumulated primarily in this sand, as a well-developed, small, severely fractured dome exists. On a smaller scale than at Salt Creek there are definite surface indications of oil. The crest of the dome is closely encircled by a sandstone escarpment which at several points gives a distinct gasoline odor. A large calcite dike crosses Section 3, in which the writer once found considerable paraffine. Wells drilled on the crest found oil in the Shannon, while others have developed oil in the shales below. Reasons for believing the Shannon and shale oil at Salt Creek and Big Muddy have origin in the Frontier sands have already been submitted. Oil is being continuously driven by hydrostatic pressure from sands in which it accumulated, freely through wide fissures, slowly through less open fractures. The movement upward from the top sand is unobstructed and comparatively rapid. Much of it evaporates at the surface. The second and succeeding sands, on the other hand, have no such unobstructed outlet, flow from them being obstructed by the first sand. When, however, no oil—only water—is found at the crest of the dome in the first sand of a field, it is certainly not a favorable condition in considering the chances of finding oil in the second sand. The loss of oil through migration from the sands, its dissemination and evaporation at the surface, is immense. Were one able, instrumentally, to look at the air stratum at the surface of Salt Creek, he would no doubt see gases steadily rising over the whole productive area. The gases probably leave the heavier oil products when they reach the aerated zone, 20 to 40 feet below the surface.

The productive area in the first sand at Salt Creek covers, perhaps, 4,600 acres, while the second sand will produce from 23,000 acres,

plus. At Grass Creek the first sand produces from a small area, indeed, while succeeding sands produce from a comparatively large territory. It is not, perhaps, unreasonable to suggest that more oil has escaped from Salt Creek, and possibly Grass Creek as well, than will be recovered.

At Elk Basin, a highly faulted dome, on the Montana-Wyoming line, the Frontier horizon contains two producing sands, in the lower of which the oil apparently accumulated originally. This lower or second sand has a thickness of 40 feet and is coarse to conglomeratic. Of the sands the writer has seen in Wyoming, it appears to have the best character as an oil reservoir. The first sand, 200 feet above, is perhaps 100 feet thick; it is a "dry" sand—contains no water, and the oil found in it is probably secondary, having migrated from the second sand. Lacking water in the sand, the oil lacks pressure; lacking pressure, the sand is not well saturated; lacking full saturation, the wells producing from it are not usually large. Some wells within the second sand productive area have shown a negligible quantity of oil in the first sand. In the absence of supporting water, oil has been found in first sand well down on the flanks of the structure.

The subject of migration is involved and is also most difficult in its application. The lack of proper fault fissures or other vent for the accumulated gases has more than once proved disastrous to our hope of finding oil. Gases doubtless occupy the crests of the domes far ahead of the approaching oil. They begin to rise to the high points at the time of original generating movement. At Grass Creek, which is crossed by one large fault and possibly many minor ones, the first producing oil sand at the crest is at a depth of about 600 feet, and little or no gas accompanies the oil. At Buffalo Basin, only a few miles distant, there are twin domes. The upper sand at the crest of the more shallow eastern dome lies at 1,400 feet depth. In the course of careful mapping no apparent faulting associated with these domes was found and no oil has been developed at Buffalo Basin, though gas wells as large as one hundred million feet capacity have been reported. A reasonable amount of faulting, providing a means of escape for the gas, may be a favorable feature in a dome where oil is desired. It is noteworthy that the gas at

Buffalo Basin is dry. Found from 1,400 to 1,700 feet, its initial closed or rock pressure was around 750 pounds. Regardless of the apparent circumstances, the writer believes that gas with large volume and rock pressure will be, for practical purposes, dry. Gas, when initially accumulating, is probably wet; as the pressure mounts the heavier or wet constituents are condensed, drop out, and become associates of the gas. At Big Sand Draw, Fremont County, Wyoming, it is reported that the Producers and Refiners recovered 6 barrels of kerosene in a few hours from one well, with the gas escaping from a partially open valve and striking an obstruction in the tank. An analysis of the gas showed it to be dry. At McMahon Terrace, Park County, Wyoming, gas was found in the Frontier at 2,230 feet. On occasions, when the valve was opened, it was reported that several barrels of gasoline (estimated, no doubt) gushed from the well. The gas, however, had 900 pounds pressure and was dry. Nature has provided her own compressor plant.

At Mule Creek—a small, sharp structure—paraffine oil has been found in the Lakota (basal member of the Cloverly). It is possible that oil has migrated from the Pennsylvanian rocks below, although we have heretofore found no paraffine oil in the Pennsylvanian of Wyoming. It may have had its origin within the fresh water red rocks adjacent, although many geologists doubt that the "red beds" contain organic matter of character to provide petroleum. The oil may owe its origin to the doubtless petroliferous shales above the Dakota. The Dakota now contains only water. Oil originating in overlying strata may accumulate in underlying beds. At Mule Creek it is suggested that the Dakota may once have been petroliferous. Oil migrating laterally and even upwards across beds may enter lower strata. This is especially possible in a sharp structure like Mule Creek.

The Muddy-Dakota horizon is an important producer of light paraffine oils. Lance Creek, Rock River, Ferris dome, Lost Soldier, etc., of southern Wyoming, produce from the Muddy or Dakota, or both.

West of Denver and two miles south from Morrison the Muddy sand locally shows heavy saturation of paraffine base oil. A very

slight buckling in the steeply dipping stratum seems to be the only excuse for this accumulation. The sand is exposed in a hogback from the Wyoming state line to Colorado Springs and beyond. The amount of local saturation suggests the vast quantity of oil that may have been driven from this long outcrop. The lack of stain in the rocks adjacent to the saturated area suggests that ordinarily the light paraffine oils leave no apparent stain in exposed rocks traversed. An instance may be observed at Cottonwood dome, east of Cody, Park County, Wyoming, where Cottonwood Creek, traversing the crest at one point, partly exposes the Frontier sands. At the time of investigation the sands showed no stain, although in adjacent wells penetrating them they showed oil. One sand was partly covered by water, and fragments taken from below the water line were saturated with oil. This instance suggests that where unprotected, the light oil evaporates before reaching the exposed surface. The various constituents of this paraffine oil are practically colorless, and absence of stain at the outcrop of the containing sand does not indicate that oil will not be found within it at favorable trap adjacent. At Oregon Basin, Park County, Wyoming, the Frontier sands outcrop in the crests of two domes; they show no stain at exposure and yet where penetrated at a distance below the surface in adjacent wells, light showings of oil were found. When under proper cover these sands probably once contained quantities of oil.

In Wyoming asphaltic oils of various grades, but usually quite heavy and low in gasoline and kerosene, are believed usually to have originated in the Pennsylvanian. This oil has been developed in several fields.

In the San Juan field, southeastern Utah, light paraffine base oil of Pennsylvania grade has been developed in the upper Hermosa beds (Lower Pennsylvanian) locally called the Goodridge. The series consists of shales, sands and limestones. In this particular instance the San Juan River has cut through two adjacent domes and exposed the sands, the supporting water has been liberated and the oil has gravitated to the trough between. Oil has been found in several wells and in various sands. Two or three igneous dikes are on the east flank of the west anticline, but there appears

to be little or no metamorphism of the rocks adjacent and no reason appears for believing that oil has been destroyed. It is suggested that the relatively small amount of heat from the igneous rocks may have had a beneficial effect in assisting the distillation of the oil from the limes and shales.

At McElmo dome, Montezuma County, southwestern Colorado, and 40 miles east of San Juan field, live oil was found at an exposure on the west flank, in calcite filling a 4 foot fissure. Ute Mountain, just south of the dome, and associated with it, is a large igneous plug. A well drilled found some gas and light oil, not in commercial quantities, but apparently unaltered, in about the Shinarump (lower Triassic) horizon. Within the Goodridge series, reached at 3,300 feet, the sands were found to be largely calcareous. Some water was found in one sand and below it in another, a slight show of green oil, followed by two to four million feet of gas, estimated. The well was abandoned at 4,190 feet. The conditions suggested that some cracking of the oil, due to excessive heat, may have taken place. Also, that heat may have caused an abnormal circulation of waters carrying lime, which in large measure cemented the sands.

The Rocky Mountain Region is replete with special conditions—more apparent there than in some other areas, perhaps, because displayed in a large way. Limited time has necessitated the selection of only those deemed most interesting for this occasion.

DISCUSSION

H. W. C. Prommel: I wish to call attention to the Bolton Creek oil field in Wyoming. In this field the first sand encountered is the Dakota which is distinctly a water-bearing sand. The second sand encountered is the Sundance. Oil was encountered at the top of the Sundance, water was encountered near the middle and oil was encountered near the base of the Sundance. Oil was also encountered in a sand near the base of the Red Beds. It seems, therefore, that in this field the presence of water without any showing of oil in the first sand was not a bad indication as far as the presence of oil in the lower sands was concerned.

R. E. Collom: In the Ventura field, Ventura County, California, the drill first enters sand strata containing either high gravity oil (45–50° Bé), flowing water or high pressure gas. These strata, whatever the fluid content, are almost impossible to correlate from well to well. The gas pressures are much

higher than normal hydrostatic pressures for the depths at which the gas has found reservoir. This condition suggests that gas has moved into these present reservoirs, through the major fault planes, from the deep-seated reservoir of oil and gas and, further, that the upper high gravity oil is a condensate from these deep-seated gases which found reservoir in the upper sands.

J. L. RICH: With reference to the theory that the presence of water with no show of oil in the first Wall Creek sands at Teapot dome is a very unfavorable indication of the oil possibilities of the sands below; I would suggest that it is entirely possible that conditions of circulation of water might flush one sand while leaving a large accumulation of oil in another sand above or below in which water circulation is less free.

SUBSURFACE CONDITIONS IN THE HEAVY OIL-PRODUCING AREA OF SMACKOVER, ARKANSAS

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The Smackover oil field is now about eight months old (March 20, 1923) and has been rapidly developed to a large proved acreage. There have appeared but few published conclusions on subsurface conditions there. The field has produced nearly 15,000,000 barrels to date, most of it being of the heavier gravities, ranging from 18 to 25 degrees Baumé. The present total daily production is almost 100,000 barrels.

On December 20, 1922, a preliminary circular to operators[2] was sent out from the Dallas office of the U. S. Bureau of Mines. This paper was meant to call the attention of the operators to some of the things that seemed quite apparent at that time without awaiting conclusive proofs. Some of this report is incorporated in the present paper.

ARTESIAN TOP WATERS

Much trouble has been experienced and several holes lost due to comparatively shallow artesian waters. In the vicinity of Sec. 1, T. 16 S., R. 16 W., such high-head waters are reported to occur at about 350 feet and 950 feet. Many logs show a predominance of sand over shale down to 1,300 feet, some showing practically all sand, with only a few shale breaks, over this range. Hence in drilling these upper formations with rotary there is often practically no mud fluid formed. The sands are quite loose and are usually not walled up with the rotary. It is therefore difficult to handle the drill pipe and casing and in some cases it has been necessary to

[1] Published by permission of the Director. The information upon which this report is based was obtained largely from the operating companies. P. S. Haury and R. B. Kelly of the Bureau of Mines assisted in its preparation.

[2] H. W. Bell and C. O. Rison, "Notes on the Smackover Field, Arkansas," U. S. Bureau of Mines.

start a new hole. In numerous wells it has been found necessary to use as many as three strings of casing and to allow the artesian water to flow out on the ground.

The control of this upper water by plastering of the sand walls is quite a problem at Smackover and the situation calls for better methods as insurance against loss of hole or trouble with fishing or possible unequal settling of the derrick.

It is said that these upper strata will take excessive quantities of mud and that in some cases it is impracticable to mud them off even with the aid of clogging material. This condition may be due to the fact that good mud is not applied until after considerable sand strata have been drilled through; that is, after the artesian water has a good start and the hole has caved considerably. In that way the mud is probably continually thinned and washed away before it can seal the sand effectively. It has been proved that each sand can be profitably mudded as it is encountered, with the aid of clogging material or with straight mud and the difficulty thus overcome.

The question of mud supply is not easily disposed of. In some parts of the field mud can be found as surface soil, but where this is not the case it may pay to transport good mud from considerable distances. Arrangements should be made for a fair supply of mud before progressing with the drilling, and it would probably pay to construct pits and ditches and separate mud and fine sand from the soil. A small amount of fine sand in the mud would no doubt be desirable for this work as it would aid in clogging.

In this work it may prove feasible to circulate cement, both on account of its weight and on account of its wall-forming qualities. The experiments of Knapp, subsequently referred to, and the field experience of Rison, show the advisability of experimenting with a cement "mud" (agitated in the hole beyond its final set—about six hours) for the upper water. Care must be taken to avoid settling out cement in the ditch with the cuttings. Cement is not considered the best material for this work but emergencies may occur when it is the only material available that is heavier than ordinary mud, and what is known of the use of cement for this purpose warrants experiments to determine its use at Smackover.

Iron oxide, on account of its high specific gravity, has been successfully used in the Monroe, Louisiana, gas field for holding back artesian water and gas that has leaked into the upper water strata. This material has also been used to some extent for similar control at Smackover, and the results warrant its further use there. Stroud[1] has described the properties of iron oxide and its use in wells. Muds as high as 16 pounds per gallon (about twice the weight of water) can be made and used if necessary. The last quoted price of iron oxide is $38.20 per ton F.O.B. Shreveport in carload lots of 25 tons or more. Knapp[2] considers that iron oxide should not be left permanently in a well on account of its promoting corrosion of the casing. It is the understanding of the writer that the iron oxide used successfully in oil and gas wells, is the natural ore ground to pass 200 mesh screen and that a chemically prepared product is not heavy enough for the purpose. It seems likely that pure ferric oxide would not affect corrosive processes, but that ferrous oxide or hydrous ferrous oxide are electro-negative to iron and stimulate corrosion. If such is true, information can well be sought on the corrosive effects of different percentages of the lower iron oxides in the commercial product. The question of whether the use of iron oxide will pay in the long run and under what conditions is problematic as yet.

Barytes (barium sulphate) is a promising material with which to make heavy mud. It has about the same weight as iron oxide and appears to have better mudding qualities, and it is obtainable, ground to 300 mesh, at no greater cost than iron oxide. Although barytes material has not been tried as a mud in wells, some experiments of Ben K. Stroud indicate that working tests may prove it valuable for controlling high pressures. If the high grade white product is employed the color would no doubt prove useful in well work by indicating its presence. It appears very unlikely that it could accelerate corrosion of the casings, and the material is certainly worthy of trials in wells.

[1] Ben K. Stroud, "Mud Laden Fluids and Tables on Specific Gravities and Collapsing Pressures," *Technical Paper No. 1*, State of Louisiana, Department of Conservation.

[2] Arthur Knapp, "Action of Mud-laden Fluids in Wells," *Mining and Metallurgy*, December, 1922.

The above discussion of heavy and workable muds, although of a general nature, is considered particularly important for the Smackover area, especially where it is impracticable to obtain a good quality of mud locally. The program for drilling, casing, and mudding will have to be varied with the local conditions, but the following general plan is suggested:

1. Carry a string of $15\frac{1}{2}$-inch or $12\frac{1}{2}$-inch to a shale at about 300 feet deep or at some point above the first artesian water, using casing mud to wall the hole. This casing should be well cemented, which may be difficult of accomplishment unless the hole is kept from caving excessively.

2. Drill into the first artesian water and mud it off thoroughly before drilling deeper. It would be good insurance to have a bradenhead attached to the conductor string, somewhat below the rotary table, and if it were fitted with a split gland, the drill pipe could be packed off and mud forced into the sands under extra pressure as soon as the water broke in and before extensive washing, dilution, and caving had occurred. It is likely that an extra closed-in pump pressure on the drilling mud does not materially aid in permanently sealing off flowing water. However, the increased pressure forces the mud farther into the formation and builds up a thicker deposit on the walls of the hole. This condition will probably hold the water back long enough to get the casing in. This is especially true if there is used a heavy and fluid mud, that is, one which is heavy due to the presence of heavy mineral, and yet not too stiff. After the casing is set and cemented, the mud and water can be held by packing off between casings, if there is a conductor above the first flowing water.

3. The second casing may be the final water string if the formations have been properly mudded, thus saving the cost of an intermediate string of pipe and consequent reduction in size of the hole. In any event the water string should be landed in a water-tight formation and well cemented, using at least 150 sacks cement in the operation.

On account of the difficulty of keeping pipe free in the hole and on account of the ease of drilling the upper strata, it may be found feasible to construct some sort of a light bit which could be

rotated down with the casing that is to remain in the hole. After the casing is cemented the bit could be milled up or otherwise disposed of. This idea might be developed and used to advantage.

The above program makes no adequate provision for the protection of promising upper oil shows that have been noted in a number of wells at varying depths. A well in Sec. 1, T. 16 S., R. 16 W., is said to have had a better showing of oil on the ditch at 940 feet than it had from the regular producing zone. The protection from water infiltration of oil as shallow as this can probably best be accomplished by mudding the formations under extra closed-in pump pressure of at least 150 pounds until practically no more mud will enter the formation. This method appears advisable on account of (1) a probable considerable vertical range of oil and gas showings; (2) the saving of casing and keeping the hole large; (3) the probable inability to protect the upper oil deposits by using large quantities of cement on account of the friction created by caving walls.

Upper oil deposits may yield commercial production in the future but water infiltration would no doubt ensue rapidly with the present average methods of drilling. When practicable these upper showings should be tested while drilling in order to know about how far to go in their protection. These deposits should be at least tested before final abandonment but lack of protection beforehand may neutralize the good results that may have otherwise obtained.

STRUCTURE

With the preliminary report of the Bureau of Mines, referred to previously, a generalized structure contour map of the heavy oil-producing area was presented. It is now apparent that the preliminary map needs revision, although the probable accuracy of the various well logs used has not been determined.

There is a strong suggestion of a synclinal basin entering from the north and having as its approximate axis the line between townships 15 S., 15 W. and 15 S., 16 W. There was not enough conclusive evidence at hand to decide fully whether an anticlinal nose structure such as was shown on the preliminary map exists in Sec. 36, T. 15 S., R. 16 W., or whether this area is the westerly flank of a synclinal basin, as is shown by the accompanying map (Fig. 1).

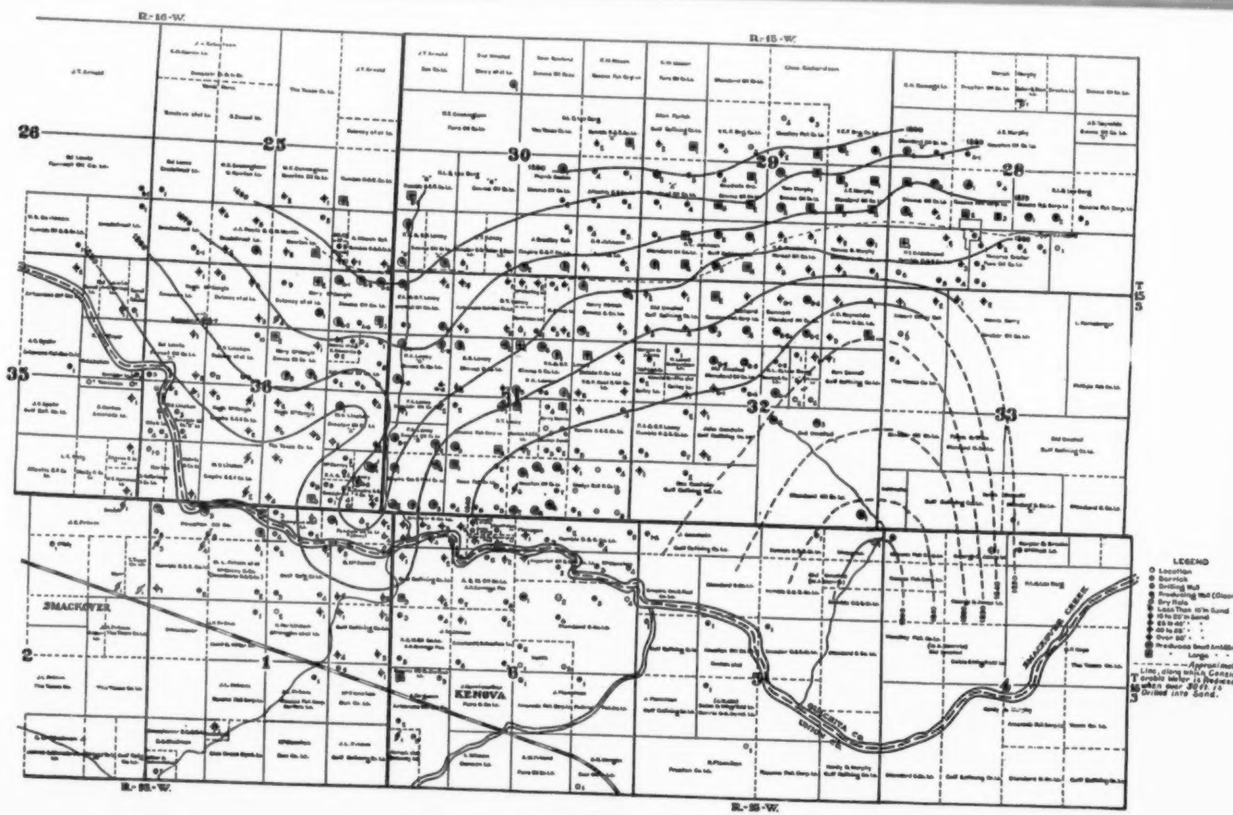
R-16-W.
R-15-W.
26
25
30
29
28
35
36
31
32
33
2
1
6
5
4
SMACKOVER
KENOVA
LEGEND
R-15-W.
R-16-W.

FIG. I

The preponderance of evidence to date points to the latter condition.

While the contouring of the eastern portion of the heavy oil area can be done with reasonable certainty, the western portion occupying sections 25, 36 and 35 in T. 15 S., R. 16 W., and portions of 30 and 31 in T. 15 S., R. 15 W., offers a more difficult problem. Logs of certain wells indicate a more pronounced syncline than is shown on the accompanying map. Some of the data have therefore been discounted and the contouring is generalized, especially in the area mentioned.

The contouring has been done on the top of the sandy zone that carries the oil and gas, which point has sometimes been taken at the top of a sandy shale. Where a cap is logged at the top of a sandy series the contour control point has always been selected at the base of the cap rock. The accompanying diagrammatic "sand section" (Fig. 2) shows specimens of logging of the sand series and the probable points of correlation of some of the wells.

If a marked syncline exists along the north-south line between T. 15 S., R. 15 W., and T. 15 S., R. 16 W., the preliminary production data for the synclinal area, showing that wells can be drilled fairly deep without producing much water, must be considered. Both theoretical considerations and the data of some other oil fields show that, other things being equal, oil may accumulate lower down in the reservoir formation in a synclinal basin than it will along an anticlinal nose. This may account for the disparity in the apparent position of the salt water in the eastern and western portions of the area discussed.

In general, the Smackover oil and gas sands probably have a high porosity and are open textured, but these factors vary considerably from well to well. The rapid decline in gas pressures and the figures for initial productions point to these conditions.

The reservoir formations appear to be more uniformly porous in the anticlinal than in the synclinal area, as is shown by data on initial productions. They average considerably higher by about 50 per cent in the anticlinal area and are more uniform. Initial productions for the synclinal area show a great variance.

A number of the logs suggest either inaccurate measurements or sharp folding or faulting. Faulting may possibly be the cause of a

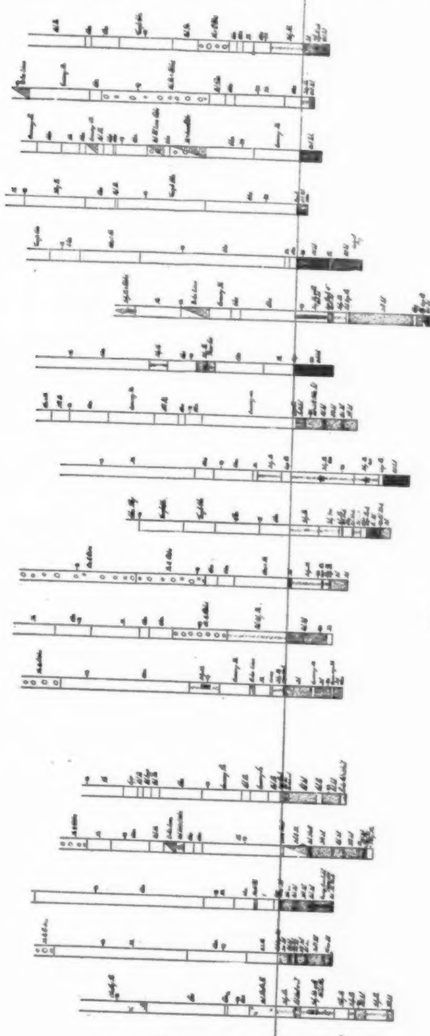

FIG. 2

difference in gravity of the oil of the heavy oil pool, and of the light oil area to the west and southwest, the maximum difference amounting to about 10 degrees Bé. The oil of the area under discussion is said to vary somewhat in short distances.

A rock pressure of 837 pounds is reported for the El Dorado Natural Gas Company well in the northwest corner of Sec. 17, T. 16 S., R. 15 W. A rock pressure of 1,063 pounds is reported for the Greenwood-McDuff well in the southeast corner of Sec. 12, T. 16 S., R. 16 S. These wells are 2 miles apart and have a difference of 226 pounds in their reported closed pressures. Such a condition suggests lack of continuous porosity in the reservoir between the two locations, which again suggests a sealed fault, or lenticular or cemented sand conditions. However, there is little doubt that the reported rock pressure of 837 pounds for the El Dorado Natural Gas Company well is low on account of its being only a half mile from the famous Murphy crater well in Section 8. Instead of being a rock pressure, it is a sort of a working pressure, the gas moving past the well toward the crater. There is no way of estimating the original rock pressure in the vicinity of the crater.

The average elevation of the main petroleum reservoir is something like 100 feet higher in the Smackover field than is the case for the El Dorado field. The Smackover structure is much more pronounced and has trapped more oil than that at El Dorado.

COMPOSITION OF THE PRODUCING ZONE

A great many logs of the producing wells of this area do not log oil or gas and correlation is thereby rendered more difficult. The accompanying sand sections (Fig. 2), made up of representative wells, show a variable composition, no doubt considerably more than actually exists. In general the logging shows a rather heterogeneous mixture of sand, sandy shale, and shale with minor partings of rock and lime. The sands vary from hard to soft and the hard sands are probably effective to some extent as fluid barriers.

In some wells several different oil and gas strata are logged, but a wide correlation of these or of barrier rocks appears to be impracticable. It is likely that these partings are effective barriers over at least limited areas. From a study of reported depths to

the salt water in wells scattered over the heavy oil area, it appears that the oil and salt water contact or contacts have a more nearly level attitude than the top of the reservoir formations. This may be taken to indicate that the partings are not fully effective in confining the oil or that the deeper oil sands of the series have less areal extent than the upper pays. The latter hypothesis is strengthened by data showing that wells can be safely drilled farther below sea level when they are high on the structure. This gives a general in-structure, downward slope for the oil-water contacts, which condition would be difficult to explain by assuming ineffective partings.

Of 20 wells selected, on account of lending an apparent clew to the position of contact of oil and water, the contour control of the sand is from 1,835 to 1,884 feet below sea level, as shown by the accompanying tabulation. The range of depths to the water below sea level is from 1,905 to 1,947 feet. The depth of salt water below the top of the sand is thus indicated to be from 48 to 102 feet.

From the production data available it seems improbable that a well in this field can be drilled as much as 100 feet below the top of the main productive series without encountering salt water, regardless of the position on the structure. The data presented in the table are based principally on the depths at which salt water was known to have been encountered in drilling. These would not necessarily define the possible positions of edge water that would show after a few days production. The selection of the top of the series is often a matter of guess as it was in the case of the maximum stratigraphic depth of 102 feet on the 1,837 foot contour. However, in this case the point was taken at the top of a formation logged "sandy shale with oil sand." There is of course always the possibility that oil and gas may reach higher stratigraphic positions in some locations than others, due to the varying effectiveness of the cap rock as a barrier. It should also be remembered that in drilling in a well, the location of salt water, unaccompanied by oil, may be determined, but the presence of water in the bottom of an upper sand that also carries oil would probably not be detected. Hence it is only with the aid of accurate production data for oil, water, and emulsion, that reliable deductions can be made for

positions of the lower water. Extensive information of this character was not available for this paper.

As suggested, the combined drilling and production data at hand indicate a considerable difference in the oil accumulation in the synclinal area of the western and the anticlinal area of the eastern portion of the north flank of the general fold. The tabulation of salt water depths previously mentioned is based largely on information obtained while drilling. Using these data in conjunction with figures for production the following tentative estimates for safe drilling depths are given for both areas. The synclinal area occupies approximately the west halves of sections 30 and 31, T. 15 S., R. 15 W., and the east half of section 36, T. 15 S., R. 16 W., the anticlinal area occupies the remaining portion of the field to the east of the assumed syncline.

TENTATIVE FIGURES FOR SYNCLINAL AREA

Depth top of sand below sea level.....	1,840	1,850	1,860	1,870	1,880
Probable safe depth to penetrate sand series..........................	80	70	60	45	30
Safe depth to drill below sea level.....	1,920	1,920	1,920	1,915	1,910

TENTATIVE FIGURES FOR ANTICLINAL NOSE AREA

Depth top of sand below sea level.....	1,840	1,850	1,860	1,870	1,880
Probable safe depth to penetrate sand series..........................	80	55	35	20	5
Safe depth to drill below sea level.....	1,920	1,905	1,895	1,890	1,885

The maximum difference of 25 feet deduced for the safe drilling depths along the 1,880-foot contour in the two areas, may be exaggerated on account of inaccurate data, or the interpretation thereof, concerning the several factors affecting the problem. The principle illustrated is, however, believed to be operative in the area under discussion. Figure 1 shows a dashed line which appears to bound an area, north of which there is danger of encountering salt water if more than 30 feet is drilled below the top of the sand series. Northward from this line the safe depth rapidly decreases to zero in the neighborhood of the 1,900-foot contour below sea level.

TABLE I

TABULATION OF DEPTHS TO SALT WATER PRODUCTION IN THE HEAVY OIL AREA OF SMACKOVER, ARKANSAS FIELD

Company	Section	Well No.	Lease	Probable Depth Below Top of Sand to Salt Water	Probable Contour Control of Top of Producing Sand	Probable Depth Below Sea to the Salt Water	Remarks
Newton et al.......	25-15-16	1	Poole	50	1878	1928	
Houston Oil Co.....	25-15-16	2	Cunningham	38	1884	1922	Abandoned
Amerada Corp......	36-15-16	1	H. McKenzie	65	1865	1930	Plugged back
Ark.-Maricopa......	36-15-16	1	L. C. Walz	65	1861	1926	Cemented bottom and shut off water
Duho Oil Co.......	36-15-16	2	M. McKenzie	48	1875	1923	Swabbing oil and water
Duho Oil Co.......	36-15-16	5	H. McKenzie	64+	1868	1932+	Swabs oil and no water
Empire G. & F. Co..	36-15-16	1	H. McKenzie	65	1857	1922	Temporarily abandoned
Empire G. & F. Co..	36-15-16	2	H. McKenzie	77+	1850	1927+	No water produced
Empire G. & F. Co..	36-15-16	1	Linahan	75	1848	1923	Abandoned acct. small prod. and salt water
Forest Oil Co......	36-15-16	A-3	Lewis	86	1847	1933	
The Texas Co......	36-15-16	3	H. McKenzie	61	1853	1914	
Empire G. & F. Co..	31-15-15	3	B. T. Laney	75+	1847	1922+	
Houston Oil Co.....	31-15-15	2	B. T. Laney	102	1837	1937	Plugged back and water shut off
Humble O. & R. Co..	31-15-15	3	F. A. & B. T. Laney	90	1837	1927	
Texas & Pacific.....	31-15-15	4	F. A. & B. T. Laney	82	1848	1930	
Humble O. & R. Co..	32-15-15	5	F. A. & B. T. Laney	78	1835	1913	
Simms Oil Co......	32-15-15	3	J. D. Reynolds	73	1837	1910	
The Texas Co......	33-15-15	1	A. Berry	96	1841	1937	
Ark. Nat. Gas Co...	6-16-15	1	Ferguson	82	1840	1922	Abandoned
Gulf Ref. Co.......	1-16-16	1	McDonald	55	1850	1905	Plugged back and shut off water

DISCUSSION

F. H. LAHEE: In reference to Mr. Bell's remarks on the position of the oil-water surface below sea level, I think it would be advisable to consider also the steepness of the dip of the sand as a factor concerned in the variable position of this surface. As Carl H. Beal has explained in *U. S. Geol. Survey*, Bulletin 658, where there is opportunity for relatively free circulation of fluids in a sand, the water-oil surface ir a plunging anticline is likely to be at a higher elevation on the steeply dipping flanks of the fold than on the gently dipping axial region.

PETROLEUM PROSPECTING IN MISSISSIPPI[1]

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INTRODUCTION

In the search for oil and gas in the state of Mississippi, forty-three wells have been completed and seven are being drilled (March, 1923). The completed tests have been confined to nineteen counties; the seven now in progress, to these same counties and four additional ones. The remaining fifty-nine counties of the eighty-two in the state have had, therefore, no tests.

In the first part of this paper, the wells drilled since 1919 are described, and those drilled previous to 1919 are briefly discussed in the second part of this paper, for Bulletin 15 of the State Geological Survey by E. N. Lowe, in which they were described, is no longer available.

The paper is planned to give general information about the wells, the name of the developing company, the name and number of the well, location, reported showings of oil and gas, outcropping formation, and beds penetrated by the well, together with a statement regarding the structure on which the well is located. The whole subject of prospecting is treated by counties in alphabetical order.

DEVELOPMENT SINCE 1919

Chickasaw County.—The Harley Development Company's Flaherty No. 1 well in Sec. 8, T. 13 S., R. 3 E., was abandoned at about 1,850 feet, August, 1921, a showing of oil and gas being reported from 1,800 to 1,850 feet. Flaherty No. 2 found a showing of oil and gas at 1,845 feet, and is now (March, 1923) at 2,165 feet. The well is north of Houston in the outcrop of the Clayton formation of the Midway series. It passed through the Ripley and Selma chalk about 850 feet, and through the Eutaw and Tuscaloosa

[1] Published by permission of Dr. E. N. Lowe, state geologist.

formations 1,325 to 1,375 feet. There can be little question that the sandstones and shales below 1,375 feet are Paleozoic beds.

Copiah County.—B. W. White abandoned the White No. 1 well in Sec. 15, T. 1 N., R. 3 W., at 1,836 feet. White No. 2, in the same section, reports operations now suspended at 2,148 feet. A show of gas was reported at 1,570 to 1,582 and from 1,600 to 1,623 feet. These wells are in the outcrop of the Catahoula (Oligocene) sandstone, passed through the Vicksburg and Jackson formations, and stopped in the upper half of the Claiborne (Eocene). They are not located on favorable structure.

The Marshall Oil and Gas Company's county line well, Didlake No. 1, in Sec. 6, T. 2 N., R. 1 W., was 1,725 feet in September, 1922, when operations were suspended. A showing of oil and gas was reported from 560 to 595 and 898 to 915 feet. The well is in the outcrop of the Catahoula sandstone and after passing through the Vicksburg and Jackson formations stopped in the Claiborne. It is on a small structure.

Franklin County.—The Choctaw Oil and Development Company's McGehee No. 1 well in Sec. 2, T. 5 N., R. 3. E., near Bude, was drilled to a depth of 2,525 feet, and is now temporarily suspended. There was a show of oil at 2,100 feet. The well is in the outcrop of the Citronelle (Pliocene) formation, and is now in the basal Jackson or upper Claiborne.

Hinds County.—Previous to 1919, two fairly deep tests were drilled on the Jackson anticline, 4 miles north of Jackson. Both of these stopped in the upper part of the Selma Chalk without penetrating the Blossom or Woodbine sands and as neither was on the highest part of the structure they are not an adequate test of this large anticline. During 1920 and 1921, two shallow wells were drilled near the southern edge of the anticline. Raymond, Benninger, and Beach drilled Elton No. 1 to a depth of 1,413 feet in the upper Claiborne, July, 1920. A showing of gas was reported from 600, 986 to 1,046, and 1,300 to 1,343 feet. The Elton Oil and Gas Producing Company's Elton No. 2, in Sec. 6, T. 4 N., R. 1 E., was abandonded at 1,475 feet, June, 1921. According to United States Geological Survey interpretation, fossils from a depth of 552 feet were from the Moody marl (basal Jackson).

A good showing of gas was encountered at 560 feet. Another sand with numerous fossils showed gas at 1,475 feet. In December, 1921, operations were resumed in the first well, but at a depth of 1,550 feet the hole was abandoned. As the wells are in the outcrop of the Jackson, the fossils at 552 show this formation to have a thickness of 500–600 feet.

Jackson County.—Previous to 1918, five wells had been drilled in Jackson County in the search for oil and gas. Since then four more wells have been drilled, all, no doubt, located because of escaping gas in enormous amounts at various places. The character of the gas is shown by the analyses in Table I.

TABLE I

ANALYSES OF GAS FROM ESCAPEMENT IN PASCAGOULA RIVER

	Sample No. 1*	Sample No. 2†
Carbon dioxide	4.30	5.34
Oxygen	1.12	....
Carbon monoxide	0.00	....
Methane	88.40	89.30
Nitrogen	6.10	0.27 (residue)
Ethane	....	5.07

* *Miss. Geol. Survey, Bull. 15.*

† D. B. Dow, Bureau of Mines, Petroleum Experiment Station, Bartlesville, Oklahoma.

The Gorgia Company's well, Waterman No. 1, in Sec. 4, T. 7 S., R. 5. W., was drilled to 2,434 feet and abandoned in January, 1921. A showing of oil was reported from 710 to 750 and 2,000 feet, a showing of gas at 1,323 feet, and salt water at 2,400 feet.

The Jackson County Oil Company's well No. 1 had been drilled to a depth of 1,387 feet, June, 1921. This well was drilled to test the sand in which gas was encountered at 1,323 feet in Waterman No. 1.

The Sea Coast Oil Company's well, Hibbler No. 1, in Sec. 22, T. 7 S., R. 6 W., was completed, March, 1921, at a depth of 4,000 feet. Salt water was reported at 58, 80, and 1,725 to 1,760 feet; a showing of gas was reported from 1,725 to 1,760, 2,494 to 2,536, 2,644 to 2,688, and 3,050 feet, and a light showing from 3,760 feet. The beds from 1,266 to 1,552 feet were reported upper Miocene; 2,100 to 2,150, Pascagoula clay (?) (Miocene); 2,257–2,361,

Miocene; 3,500, probably Wautubbee marl (Claiborne). A core from 3,650 feet contains numerous nummulites similar to species found in the Eocene, and it seems likely that the formation is the Claiborne. All determinations were made by the United States Geological Survey from fossils.

The Great American Oil Company is drilling a well near Pascagoula. No data are available in regard to this well.

Jefferson County.—The Manhattan Texas Petroleum Company drilled Truly No. 2, in T. 9 N., R. 1 W., abandoning it in 1921 at a depth of approximately 1,100 feet. The well was located near Lake Truly because of the escapement of inflammable gas from the surface of the lake. It is in the outcrop of alluvium of the Mississippi flood plain and there is no indication of a favorable structure.

Lafayette County.—The Lafayette Oil Company's Lafayette No. 1, 6 miles west of Oxford, was abandoned at a depth of 600 feet, May, 1922. The well is in the outcrop of the Holly Springs (Wilcox) sand and is not on a structure.

Lauderdale County.—The Baird-Hughes Drilling Company drilled the Craig No. 1 in Sec. 28, T. 7 N., R. 14 E., to a depth of 3,000 feet, March, 1921. A show of gas was reported from 2,383 to 2,479 feet.

The Citizens Oil Trust and George O. Baird drilled the Middlebrook No. 1 in Sec. 29, T. 7 N., R. 15 E., completing the well at 3,288 feet, August, 1921. A showing of gas was reported from 3,210 to 3,226 feet. The well is in the outcrop of the Wilcox and, after passing through the Midway, Ripley, Selma chalk formations, was in the Eutaw sand at 2,650 feet, and was completed in the Tuscaloosa formation. Neither the Craig No. 1 nor the Middle Brook No. 1 was on favorable structure. They were merely located near the center of a block of acreage.

Lowndes County.—The Tombigbee Oil and Gas Company drilled Hardy No. 1 in Sec. 9, T. 17 N., R. 17 E., using cable tools to a depth of 750 feet and shutting down because of caving beds. The well is on a small fold in the Selma chalk which, it is believed, reflects similar structure in the Paleozoic beds lying unconformably beneath. The well was, however, abandoned in the Selma chalk before the Paleozoic beds were reached because no progress could be made by the second company.

The Anderson Drilling Company abandoned Billups No. 1, in Sec. 12, T. 18 N., R. 16 E., at 2,030 feet in December, 1921. The well is in the outcrop of the Selma chalk. It passed through 300 feet of this formation and about 1,066 feet of the Eutaw and Tuscaloosa; and seemingly penetrated the Paleozoic beds at a depth of 1,366 feet. As there are no outcrops in the immediate vicinity, it was located without the aid of geologists.

Madison County.—The Madison County Oil and Development Company's Greaves No. 1, at the southeast corner of Sec. 4, T. 8 N., R. 1 E., near Livingston, was completed at 3,020 feet, March, 1921. A show of dry gas was reported from 1,835 to 1,879 feet. From fossils obtained from 2,000 and 2,600 to 2,650 feet, the well appeared to be in the Eocene, according to the United States Geological Survey. It is not on a favorable structure.

The same company drilled Nichols No. 1 in Sec. 7, T. 10 N., R. 4. E., abandoning it at a depth of 2,482 feet in December, 1921. The well is located on a small fold with pronounced east dip, in the outcrop of the Lisbon (Claiborne) formation. It passed through the Claiborne and stopped in the basal Wilcox, or in the upper Midway series.

According to a local newspaper report of March 9, 1923, the Roxana Petroleum Corporation has leased 12,000 acres of land in the vicinity of Cobbville, just north of Canton.

Montgomery County.—The deepest and one of the most interesting wells, from a geological point of view, that has been drilled in Mississippi, is in this county, 6 miles east of Winona. It is the Preston Oil Company's McLean No. 1, in Sec. 15, T. 19 N., R. 6 E., drilled to 3,522 feet with a rotary outfit. At this depth, a hard rock was encountered and standard cable tools were rigged up, but they were used only for a few feet, because the well passed through the hard rock into a caving sand. The well was continued to 4,260 feet and abandoned in June, 1921. Salt water was encountered from 3,503 to 3,522 feet, but disappeared later. A chloroform test of sand from a core taken from 3,412 to 3,450 feet showed oil. In order to test the sand, 120 feet of screen pipe with 80-mesh screen was set from 3,400 to 3,522, but the drillers were unable to bale out the hole, showing that water sand was encountered

between 3,503 to 3,522 feet. The well is located in the outcrop of the Tallahatta (Claiborne) formation which has a thickness of approximately 500 feet. It passes through the following formations, which have the thicknesses indicated: Wilcox and Midway, 1,400–1,650 feet; Ripley, 200–250 feet; Selma chalk and Eutaw, 600–675 feet; and Tuscaloosa, 400–450 feet. The remaining 750 feet penetrated are probably Lower Cretaceous beds, which consist of reddish-brown sand and red and chocolate-brown shale, much of which is calcareous. The red and brown shales in the 400–450 of Tuscaloosa are only slightly calcareous at a few places, whereas, those below are decidedly calcareous.

Panola County.—The Panola Oil and Gas Company's Lamb No. 1 in Sec. 35, T. 27 N., R. 2 E., near Teasdale, was drilled to a depth of 560 feet. Cable tools were installed but no progress could be made and the well was shut down at 577 feet. The well had reached a depth of 1,300 feet, March 13, 1923 using a rotary outfit. It is in the outcrop of the Hatchetigbee (Wilcox) formation.

Pike County.—The Gulf Drilling Company's Cupit No. 1, in Sec. 25, T. 2 N., R. 7 E., was capped at a depth of 1,162 feet, having a showing of gas and oil, May, 1921. In the latter part of 1922, the well was taken over by the Mid-Central Oil and Gas Company and continued to a depth of 1,554 feet and recapped. Early in 1923 operations were resumed and the well has reached a depth of 2,100 feet with a showing of oil reported. The well is located in the outcrop of the Citronelle (Pliocene) formation and passing through the Pascagoula, Hattiesburg, Catahoula, and Vicksburg formations is now probably in the Jackson formation.

Tallahatchie County.—The Charleston Oil and Gas Company's Newton No. 1 in Sec. 36, T. 24 N., R. 2 E, was drilled under the supervision of the Marland Refining Company, which abandoned the well at a depth of 3,700 feet in August, 1921. A small gas show was reported at 540 feet and from 3,280 to 3,300 feet. This well was located in the outcrop of the Hatchetigbee (Wilcox) formation and after passing through the Midway, Ripley, Selma, and Eutaw formations, stopped in the basal Tuscaloosa, or Lower Cretaceous.

Tishomingo County.—The Iuka Development Corporation's Jourdan No. 1 in Sec. 9, T. 4 S., R. 11 E., after reaching a depth of 1,900 feet with cable tools, suspended operations, July, 1922. Slight oil shows were encountered at several horizons. The Tuscaloosa appears to have a thickness of 161 feet and the Mississippian a thickness of 289 feet; the black shale at 450 feet is probably black Devonian shale. E. O. Ulrich identified fossils from 838 feet as Middle Silurian, from 1,326 to 1,380 as Middle Stones River, Ordovician, and from 1,840 feet as Ordovician beneath any known oil horizon. The well is not on a favorable structure.

The Mississippi Oil and Refining Company's Southward No. 1 in Sec. 18, T. 5 S., R. 11 E., has reached a depth of 155 feet.

Union County.—The Minyard Oil Well Company drilled a number of prospect holes through the thin covering of Ripley to the top of the Selma chalk, the elevations of the contact being referred to sea-level and the structure determined in this way. The company is now drilling a deep test, Woodson No. 1, in Sec. 36, T. 7 S., R. 3 E., near Wallerville. The well is in the outcrop of the Ripley and at 602 feet it passed through the Selma chalk into Eutaw (Blossom) sand, with a good show of gas and some oil. At 675 feet, the well penetrated another hard rock and passed into sand, with a second good show of oil and gas. The 10-inch casing is being set in the rock preparatory to making a test of the sand. A second well was located 2 miles west of Woodson No. 1 and was rigging up in March, 1923.

Warren County.—The Edmonds Oil and Refining Corporation's Archer No. 1 in Sec. 36, T. 9 N., R. 5 W., was drilled to a depth of 3,664 feet, September, 1921. A showing of gas was reported from 1,130 to 1,165, and a showing of oil from 1,740 to 1,780, and from 2,505 feet. Hot salt water was encountered at 2,822 feet. This well probably stopped in the basal Eutaw, or upper part of the Tuscaloosa.

Washington County.—The Alhambra Oil and Gas Company's first well, Williams No. 1, in Secs. 30–31, T. 14 N., R. 8 W., near Glen Allen, was junked at a depth of about 2,000 feet in April, 1922. A good showing of gas, coming up through 1,000 feet of water and burning with a flame 10–12 feet high, was reported.

Williams No. 2, drilled at the same location, was junked. Williams No. 3, several hundred feet from No. 1, is now being drilled. The 8-inch casing was set at 1,900 feet and rock drilled through with a 6-inch bit. As soon as rock was penetrated, gas, warm salt water, and a small show of oil were encountered in March, 1923. The well has reached a depth of 1,960 feet. The wells are located near the south end of Lake Washington in the Mississippi flood plain.

DEVELOPMENT PREVIOUS TO 1919[1]

Attala County.—The Home Oil Company's well, J. R. Dill No. 1, in Sec. 5, T. 15 N., R. 9 E., 3 miles north of Gladys, drilled in 1911; gas bubbles reported at 1,020 feet; well abandoned at 1,900 feet in basal Wilcox, or Midway. The well is in the outcrop of the Tallahatta (Claiborne) formation and is not on anticlinal structure.

Clarke County.—The Alabama-Mississippi Investment and Development Company's well located a quarter of a mile east of the Mobile and Ohio Railroad station at Enterprise, was drilled in 1903; a showing of oil reported from 900 and 1,600 feet; well abandoned at 1,842 feet in the Wilcox; location in the outcrop of the Tallahatta (Claiborne) not on anticlinal structure. In 1904 a well was drilled on the west side of Chickasawhay River south of Enterprise; at 400 feet, a flow of artesian water was encountered and the well abandoned.

Covington County.—The Seminary Oil and Gas Company's O. W. Conner No. 1 in Sec. 22, T. 7 N., R. 15 W., drilled to a depth of 3,300 feet in 1914. The well is in the outcrop of the Catahoula and is not on anticlinal structure.

Forrest County.—The Tatum well, near Hattiesburg, is reported to have been drilled 4,000 feet and to have encountered a strong flow of warm salt water.

Hancock County.—At least two wells are reported to have been drilled in the vicinity of Gulfport, fifteen or twenty years ago, but further information is not available.

Hinds County.—The Atlas Oil Company's Garber No. 1 well in Sec. 18, T. 6 N., R. 1 E., drilled in 1917, was located on the

[1] E. N. Lowe, "Oil and Gas Prospecting in Mississippi," *Miss. Geol. Survey Bull. 15* (1919).

Jackson anticline in the outcrop of the Jackson formation, passed through the Claiborne, Wilcox, Midway, and Ripley formations, and stopped in the upper part of the Selma chalk at a depth of 3,079 feet.

The Arkansas Natural Gas Company (Benedum-Trees Company) drilled the Swearengen No. 1, or "Big Ben," well 4 miles east of Garber No. 1 in Sec. 14, T. 6 N., R. 1 E., to a depth of 3,043 feet in 1917. A showing of petroleum was reported in limestone taken from the well at a depth of 2,640 feet. The formations penetrated are shown in Table II.

TABLE II

Formations in Arkansas Natural Gas Company's Swearengen No. 1

	Thickness	Depth in Feet
Eocene:		
Jackson		
Yazoo clay	120	120
Moody marl	220	340
Claiborne		
Yegua	240	580
Lisbon	320	900
Tallahatta	445	1345
Wilcox	692	2037
Midway	213	2250
Cretaceous:		
Ripley	346 ?	2597
Selma chalk	446 ?	3043

Jackson County.—A well was drilled at Bellevue, South Pascagoula, about 1913, and abandoned at 560 feet. An artesian well drilled on the same property showed a strong flow of hot water in sand from 700 to 810 feet.

The Pascagoula Development Company's De Lamorton No. 1 at Laine, 4 miles east of Pascagoula, drilled in 1911, reported a showing of oil at 250 and 545 feet, a showing of gas from 1,119 to 1,134, warm salt water and gas from 2,134 to 2,258, and oil and gas from 2,258 to 2,300 feet, the well being abandoned at 3,010 feet. De Lamorton No. 2, located 700 feet west of No. 1, drilled by the same company, was abandoned at 2,240 feet.

The Atlas Oil Company's Woodman No. 1, in Sec. 15, T. 6 S., R. 7 W., near Vancleave, was drilled in 1917, and was abandoned at 2,762 feet. Woodman No. 2 in Sec. 20, T. 6 S., R. 6 W., on Sand Island in Pascagoula River, was drilled in 1917 to a depth of 2,654 feet. A showing of gas was reported from 1,279 to 1,305, and 1,642 to 1,690 feet.

Jefferson County.—Truly No. 1 on the Judge Jeff Truly property, 16 miles west of Fayette, drilled during 1915–16, was abandoned at 2,575 feet, a showing of gas being reported from 870 to 885 feet. Inflammable gas escapes from the surface of Lake Truly. The well is in the Mississippi flood plain and there is, therefore, no indication of anticlinal structure.

Lauderdale County.—The Pioneer Oil and Gas Company's Knox No. 1, 2 miles southwest of Toomsuba, was drilled in 1914 to a depth of 2,850 feet. At 2,808 feet a good showing of gas was encountered, the gas burning 12 inches high at the mouth of the well, although the hole was full of mud and water.[1] In 1915, the Meridian Oil and Gas Company drilled two wells, near the knox No. 1, both to a depth of approximately 2,300 feet. These wells are in the outcrop of the Wilcox and are not located on anticlinal structure.

Tishomingo County.—The M. E. Higdon No. 1, a mile and a half south of the old Eastport landing on the Tennessee River, in Sec. 26, T. 2 S., R. 11 E., was drilled 752 feet, about 1903 or 1904. The well is reported to have been in Mississippian limestone until Devonian black shale was encountered about 400 feet, and to have had a small showing of oil. The well was not located on anticlinal structure.

Warren County.—The Mississippi Oil, Gas, and Investment Company's Mildred No. 1 well, in Sec. 32, T. 16 N., R. 4 E., drilled to a depth of 3,462 feet in 1916, is on the Vicksburg monocline and the formations were penetrated as shown in Table III.

The Mildred No. 2 in T. 16 N., R. 4 E., near the northeast corner of the National Cemetery, was abandoned at 2,630 feet. Brown sand from 1,800 to 1,825 feet gave an odor of petroleum

[1] E. N. Lowe, *op. cit.* p. 64.

when heated and light-brown, fine-grained sand from 2,459 to 2,500 also gave a strong odor of petroleum on heating. Neither of these wells penetrated the Tuscaloosa (Woodbine) and No. 2 failed to reach any of the Cretaceous sands.

TABLE III

FORMATIONS IN THE MISSISSIPPI OIL, GAS AND INVESTMENT COMPANY'S MILDRED NO. 1

	Thickness	Depth in Feet
Oligocene:		
Catahoula	30	30
Vicksburg	280	310
Eocene:		
Jackson	768	1078
Claiborne	442	1520
Wilcox	974	2494
Midway	134	2628
Cretaceous:		
Ripley	247	2875
Selma chalk	395	3270
Eutaw	192	3462

SUMMARY AND CONCLUSIONS

From surface indications twenty of the forty-three wells which have been drilled in Mississippi in search for oil and gas are not on favorable structure, and though twelve additional ones are near inflammable gas escapements, the chemical analyses show the gas to be dry. Eleven wells are on favorable structures. Two near the southern edge of the Jackson anticline are too shallow (1,475 feet) for adequate tests, two north of the Capitol are not on the highest part of the structure, and—what is of more importance—are not deep enough to test all possible Cretaceous sands, having stopped in the upper part of the Selma chalk above the Blossom and Woodbine sands. Two wells, neither of which penetrated the Woodbine formation, are on the Vicksburg monocline, and one, which stopped in the basal Eutaw or the upper part of the Woodbine (Tuscaloosa) formation, is on the El Dorado monocline. Both of these monoclines are western extensions of the Jackson anticline as mapped by Hopkins. The well on the small fold in the outcrop of the Lisbon (Claiborne) formation in the northeastern part of Madison County stopped in the Eocene above all of the Cretaceous

sands. The well on the small fold in the outcrop of the Selma chalk in southern Lowndes County was started with cable tools and abandoned at 750 feet in the Selma, because no progress could be made. The structure east of Winona, Montgomery County, could not be mapped, but the well seems to be favorably located. The well drilled by the Preston Oil Company on this structure is the deepest test in the state and was completed at 4,260 feet in the Lower Cretaceous. This well and the one on the fold south of Charleston, Tallahatchie County, were both deep tests.

From this summary it is seen that the state has not been adequately tested. It would be a strange coincidence if the Mississippi River constitutes the boundary line between productive Gulf Coast territory on the west and non-productive on the east, especially when the beds of the two areas are so similar. It is the writer's opinion, therefore, that oil and gas will eventually be found in paying quantities in Mississippi.

GEOLOGICAL NOTES

ARE THERE "RED BEDS" OF CHESTER AGE IN THE MID-CONTINENT REGION?

Many wells in Lincoln, Payne, Pawnee, Noble, and Kay counties, Oklahoma and Cowley, Chautauqua, Elk, and other counties to the north in Kansas report red shale beds in the 30 to 100 feet of strata directly on top of the "Mississippi lime." The latter consists of 200 to 300 feet of limestone, "chats" (white chert), and minor amounts of shale of Mississippian age and constitutes a marker well known to drillers in much of the Mid-Continent region: Associated with the red shales are limestones, sandstones, and gray, blue, green, and black shales. The individual beds are mostly thin, ranging from a few to 20 or rarely 30 feet in thickness. The sands have produced both oil and gas, but as a rule the wells are small and the pools of limited area. The red shale is absent in and near the Burbank pool in Osage County.

The Chester of Indiana, Illinois, and western Kentucky exhibits red and green shale both on the outcrops and where penetrated by wells, and contains oil and gas sands. At Centerville, Appanoose County, Iowa,[1] red and green shales, thin limestones and sandstones were found in a drill hole, between the coal-bearing beds of Pennsylvanian age and limestones of known Mississippian age. Associated with the red and green shales were gypsum and anhydrite beds to which a shaft has been sunk for the purpose of mining them. In other holes in south central Iowa and north central Missouri similar beds have been found at the same place in the section. The age of these beds has not been determined, but their position almost proves their age to be Chester. A bit of negative evidence is the absence of such beds from basal Pennsylvanian outcrops in nearby regions.

The gypsum at Fort Dodge, Iowa, is associated with red and green shale.[2] The age of this deposit is in question, but was believed by Stone to be Permian. According to Stone the presence of glacial drift obscures the relations of the gypsum beds to the underlying rocks and while they appear to be of post-Pennsylvanian age, in some places they rest directly

[1] G. F. Kay, *Iowa Geol. Survey, Annual Report* (1912), Vol. XXI, p. 24.

[2] R. W. Stone, *U. S. Geol. Survey Bull. No. 697* (1920), p. 106.

on the St. Louis limestone of Mississippian age. In view of the relations of the beds at Centerville, it requires little exercise of the imagination to place the Fort Dodge beds between the Pennsylvanian and the St. Louis.

Between Iowa and the Mid-Continent region, at Nebraska City, near the southeast corner of Nebraska, a deep well revealed 60 feet of red shale near the contact of the Pennsylvanian and Mississippian.[1] It is associated with limestone, white shale, and sandstone.

There is a scarcity of logs from northeastern Kansas, which does not permit the tracing of these beds to south central Kansas where the red shales apparently occur at the same position as previously mentioned.

Summarizing these widely scattered bits of evidence, it is seen that in Oklahoma, Kansas, Nebraska, Iowa, and Missouri, the red shales in question appear to be present at the same position in the section.

There is no direct evidence that they are Chester, but their position below the lowest known coal beds and above limestones of known Mississippian age, as well as the absence of such beds from basal Pennsylvanian outcrops, seems to constitute a strong argument for placing them in the Chester. Their color also links them with the Chester of Indiana, Illinois, and Kentucky.

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[1] W. H. Norton and others, *U. S. Geol. Survey Water Supply Paper No. 293* (1912), pp. 901–902.

REVIEWS AND NEW PUBLICATIONS

Current Bibliography of Foreign Petroleum Resources[1]

AIGNER, "Erdgas und Erdöl im oberosterreichischen Schlierbecken." [Natural Gas and Petroleum in the Schlier Basin in Upper Austria.] *Oest. Berg. u. Hut. Wes.* (Vienna), IV, pp. 92–94, 113–116, 1923.

ANONYMOUS, "Les gisements pétrolifëres de l'Albania." *Courr. d. Pétroles* (Paris), 4th year, No. 140, p. 2, July 7, 1923. (Excerpt from *L'Information d'Orient.*)

D'ANDRIMONT, R., "Note on the Genesis of Hydrocarbons and Their Localization in Certain Zones of the Earth's Crust." *Inst. Petroleum Tech. Jour.* (London), IX, No. 38, pp. 287–291, 1923.

ANONYMOUS, "The Oil Regions of Angola: New British Interests." *Petroleum Times* (London), X, No. 244, p. 348, 1923.

APRESOV, S. M., "Geological Structure and Oil-bearing Nature of the First Soviet Oil Plot" (Soldatsky Bazar). *Azerbaidzhanskoe Neftianoe Khoziaistvo Baku,* No. 4 (16), pp. 77–84, April, 1923. (In Russian.)

ANONYMOUS, "Petroleum Possibilities in Arabia." *Petroleum Times* (London), X, No. 246, p. 434, 1923.

ANONYMOUS, "The Argentine and Its Petroleum Possibilities." *Petroleum Times* (London), X, No. 241, pp. 239–240, 1923.

BREUER, P. K., and BROCHE, HANS, "Ueber das Vorkommen eines sehr teerergiebigen Oelschiefers in Deutschland." *Brennstoff-Chemie* (Essen), IV, No. 13, pp. 200–201, 1923.

CASTELLI, G., "Le miniere asfaltifere di Ragusa." *Rassegna Mineraria,* LVIII, pp. 136–141, June 15, 1923.

CATHERALL, A. P., "The Petroleum Industry: Trinidad and Tobago." *Administration Report of the Acting Director of Lands and Mines, etc.,* Council Paper No. 48 of 1923, pp. 2–10, Port-of-Spain, 1923.

CHAMBRIER, PAUL DE, "An Economic Study of Petroleum Mining by Underground Drainage." *Inst. Petroleum Tech. Jour.* (London), IX, No. 38, pp. 330–342, 1923. (Translated and abridged from French original by J. A. Lautier.)

CHAMBRIER, PAUL DE, "L'exploitation du pétrole par drainage souterrain." [Mining Petroleum by Subterranean Drainage.] *Univ. de Strasbourg L'Institut du Pétrole, Bull.* (Paris), I, No. 3, pp. 263–280, 1923.

ANONYMOUS, "Exploraciones de terrenos petrolíferos en Chile." *La Riqueza Minera de Chile* (Santiago de Chile), 1st year, No. 11, p. 191, 1922.

[1] Published by permission of Acting Director, U. S. Geological Survey.

COUMBE, A. T., JR., "Petroleum Production and Trade of the Dutch East Indies." *U. S. Dept. Commerce, Trade Information Bull. No. 111*, 1923.

CRAIG, E. H. C., "The Origin of Petroleum-Results of Recent Researches." *Petroleum Times* (London), X, No. 249, pp. 521–524, 1923. Also: *Oil News* (London), XIV, No. 567, pp. 362–364, 1923.

CRAIG, E. H. CUNNINGHAM, "The Riddle of the Carpathians." *Inst. Petroleum Tech. Jour.* (London) IX, No. 38, pp. 274–276, 1923.

DAY, D. T., "Petroleum and Natural Gas." *The Mineral Industry*, 1922, XXXI, pp. 499–552, New York, 1923.

DEUSTUA, R. A., *El Petroleo en el Peru.* (*Supplemento*) [Supplement to Petroleum in Peru.] 39 pp., Lima, 1922.

EMMENS, N. W., "Natural Gas and Petroleum Resources of Western Canada—Manufacture of Carbon Black." *Can. Mng. Jour.* (Gardenvale), XLIV, No. 41, pp. 796–799; No. 42, pp. 817–819, 1923.

EMMONS, NEWTON W., "Natural Gas and Petroleum Resources of Western Canada." *Can. Mng. Jour.*; XLIV, pp. 431–433, 477, 544–545, 721–725, 739, 742, 1923.

FARQUHARSON, R. A., "An Occurrence of Impsonite in Western Australia." *Roy. Soc. Western Au. Jour. & Proc.* (Perth), IX, Pt. I, pp. 8–22, 2 plates, 1923.

GAULT, H., et BOISSELET, L., "Étude de schistes bitumineux de Bourbon-Saint Hilaire." [Study of Oil Shales of Bourbon-St. Hilaire.] *Univ. de Strasbourg L'Institut du Pêtrole Bull.* (Paris), I, pp. 229–240, 1923.

GAULT. H., and NICLOUX, MAURICE, and others, "Sur les macro- et micro-méthodes d'analyse elémentaire des schistes bitumineux." [On the Macro- and Micro-Methods of Elementary Analysis of Oil Shales.] *Univ. de Strasbourg L'Institut du Pêtrole, Bull.* (Paris), I, No. 1, pp. 213–227, 1923.

GAULT, H., "Quelques problèmes actuels de l'industrie des huiles minérales." [Some of the Present Problems of the Mineral Oil Industry.] *Univ. de Strasbourg L'Institut du Pêtrole, Bull.* (Paris), I, No. 3, pp. 173–203, 1923.

GIFFARD, H. P. W., "The Recent Search for Oil in Great Britain." *Mng. Inst. of Scotland, Transactions* (Glasgow), XLIV, Pt. II, pp. 31–60, 9 figures, 1923.

GIFFARD, H. P. W., "The Recent Search for Oil in Great Britain." *Inst. Mng. Eng., Transactions*, XLV, Pt. V, pp. 221–250, 9 figures, 1923.

GIGNOUX, "Sur la structure géologique des gisements de pétrole de l'Italie du Nord." [Geologic Structure of the Petroleum Deposits of Northern Italy.] *Univ. de Strasbourg L'Institut du Pétrole, Bull.* (Paris), I, No. 3, pp. 249–258, 1923.

GOLUBIATNIKOV, D. V., and others, "Papers and Debates on the Question of Water Troubles in the Baku and Grozny Oil-bearing Areas." *Neftianoe i Slantzevoe Khoziaistvo* (Moscow), III, Nos. 7–8, pp. 321–367, 1923. (Text in Russian.)

GREAT BRITAIN—*Report from the Select Committee of the House of Lords on the Petroleum Bill* [H. L.], 99 pp., London. 1923.

GUTHRIE, W. A., "Heavy Grade Egyptian Crude Petroleum." *Inst. Petroleum Tech. Jour.* (London), IX, No. 38, pp. 212–247, 1923.

HAUTPICK, E. DE, "Sun Energy the Source of Oil." *Mng. Jour.* (London), CXLII, No. 4591, pp. 631–632; No. 4592, pp. 646–647, 1923.

HOFER, HANS VON, "Das Wasser in den Erdölfeldern." [Water in the Oil Fields.] *Petroleum* (Berlin), XVIII, No. 6, pp. 201–206, 2 figures, 1922.

ICKES, E. L., "Recent Exploration for Petroleum in the United Kingdom." *Amer. Inst. Mng. & Met. Eng., Transactions,* No. 1279-P., 23 pp., 2 figures, 1923.

JAHN, J. J., and SCHNABEL, E., "The Occurrence of Asphalt near Strecňo on the Vah in the Vicinity of Zilina in Slovakia." *Věda přirodni* (Prague), Jg. 3, 2 pp., 1922. (Text in Czech.)

JUNG, JEAN, "Une application du microscope au diagnostic des horizons marins dans les marnes pétroliferes." [Application of the Microscope to the Diagnostic of the Marine Horizons in Petroliferous Marls.] *Univ. de Strasbourg L'Institut du Pêtrole, Bull.* (Paris), I, No. 3, pp. 259–262, 1923.

KENNY, E. J., "Oil Prospecting Operations of the Tamworth Oil Prospecting Company near Tamworth, New South Wales," *Ann. Rept. Dept. Mines,* 1922, p. 99, 1923.

KHUTZIEV, A., "Geological Sketch of the Oil Feilds of the Khnyss Kala Plateau" (Turkish Armenia). *Azerbaidzhanskoe Neftianoe Khoziaistvo Baku,* Nos. 6–7 (18–19), pp. 46–52, 3 figures, June-July, 1923. (In Russian.)

KRAUS, MAXIMILIAN, "Oil Deposits and the Tectonics of Vertical Pressure." *Inst. Petroleum Tech. Jour.* (London), IX, No. 38, pp. 276–287, 19 figures, 1923.

LEE, WALLACE, *Reconnaissance Geological Report of the Districts of Payap and Maharashtra, Northern Siam* (Bangkok), 16 pp., geol. map, 1923.

LEITCH, G. F., "Notes on the Occurrence of Oil on the Shore of the Australian Bight." *Ind. Aus. and Mng. Stand.* (Melbourne), LXX, No. 1814, p. 361, 1923.

LEITCH, G. F., "Variations in the Terrestrial Magnetic Field of Australia as Applied to Possible Oilfields." *Ind. Aus. & Mng. Stand.* (Melbourne), LXX, No. 1816, p. 436, 1923.

LEVI, GEORGES, "Le régime légal des recherches de pétrole en France et aux colonies." [Laws and Regulations Relating to the Search for Petroleum in France and Her Colonies.] *Univ. de Strasbourg L'Institut du Pêtrole, Bull.* (Paris), I, No. 3, pp. 281–291, 1923.

LINDTROP, N., "Results of the First Analyses of the Petroleum Gas of the Grozny Region." *Grozrienskoe Neftianoe Khoziaistvo* (Grozny), Nos. 5–8 (14–17), 1923, pp. 48–52, 1923. (Text in Russian.)

LINDTRON, I., "Rational Exploitation of the Grozny Region." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 1–2 (10–11), 1923, pp. 10–16, 1923. (Text in Russian.)

LIDGETT, ALBERT, "The Oilfields of Roumania." *Petroleum Times* (London), X, No. 246, pp. 409–410, 1923.

LONGOBARDI, ERNESTO, "Petroleum Reserves in Bolivia and the Argentine Republic." *Pan-American Union Bull.*, LVII, No. 1, pp. 16–24, Geol. map, 1923.

K. M., "Exploitation of Oil Wells of Small Productiveness." *Azerbaidzhanskoe Neftianoe Khoziaistvo Baku*, No. 4 (16), pp. 20–24, April, 1923. (In Russian.)

MATHER, KIRTLEY F., "The Underground Migration of Oil and Gas." *Denison Univ. Sci. Lab. Jour.* (Granville), XX, pp. 155–185, 1923.

ANONYMOUS, "The Oil Shale Mines in 1921–1922." *Gornyi Zhurnal* (Moscow), XCIX, Nos. 1–2, p. 75, 1923. (Text in Russian.)

NORTH, SYDNEY H., *The Petroleum Year Book*, 1923. 460 pp., London, 1923.

NOTH, RUDOLF, "Migration und Salsen." [Migration and Mud Volcanoes.] *Zeitschr. d. Int. Vereines de Bohring. u. Bohrtech.* (Vienna), Jg. 31, No. 17, pp. 130–135, 4 figures, 1923.

MARCKWALD, EDUARD, "Die Asphaltlager von Lattakia." [The Asphalt Beds of Lattakia.] *Petroleum* (Berlin), XVIII, No. 5, pp. 165–170, 1922.

ANONYMOUS, "The Oilfields of Mexico." *Petroleum Times* (London), X, No. 240, pp. 201–203, 1923.

MIRONOV, S. I., and others, "Prospects of Development of Oil Industry as Determined by the Available Reserve of Oil-bearing Lands and the Programme of Work for the Coming Quinquennial Period." *Neftianoe i Slantzevoe Khoziaistvo* (Moscow), III, Nos. 7–8, pp. 383–422, 1922. (Text in Russian.)

K. P., "Geologic Investigations in the Explored Regions of Grozny." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 3–4 (12–13), 1923, pp. 6–10, 1923. (Text in Russian.)

ANONYMOUS, *Petroleum Glossary.* Published by American Petroleum and Transport Co., 52 pp., New York, 1923.

ANONYMOUS, "Petroleum in the Philippines." *Petroleum Times* (London), X, No. 243, p. 328, 1923.

PIUKHIAL, E., "The Genesis of Petroleum." *Azerbaidzhanskoe Neftianoe Khoziaistvo Baku*, Nos. 6–7 (18–19), pp. 74–77, June-July, 1923. (In Russian.)

PLENKIN, F., "The Petroleum Industry in 1921–1922." *Gornyi Zhurnal* (Moscow), XCIX, Nos. 1–2, pp. 67–74, 1923. (Text in Russian.)

PORTILLO Y WEBER, JOSÉ LOPEZ, "La industria de la refinación del petroleo en Mejico." [Petroleum Refining in Mexico.] *Soc. Cient. "Antonio Alzate," Mem. y Rev.*, XLII, Nos. 1–2, pp. 33–112, 6 plates, Mexico, 1923.

ANONYMOUS, "The Production of the Grozneft for the 1923–24 Operating Year." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 5–8 (14–17), 1923, pp. 83–90, 1923.

PURINGTON, CHESTER WELLS, "The Coal and Oil Resources of Sakhaline Island." *Mining and Metallurgy* (New York), IV, No. 201, pp. 453–461, maps, 1923.

RAO, M. VINAYAK, "Note on the Oil Shales of Mergui." India, *Geol. Surv. Rec.*, LIV, Pt. III, pp. 342–343, 1923.

ANONYMOUS, "Progress of the Phoenix in Roumania." *Oil News* (London), XIV, No. 565, pp. 304–307, illustrated, 1923.

ANONYMOUS, "The Oil-producing Districts of Russia in the First Third of the 1922–1923 Operating Year." *Gornyi Zhurnal* (Moscow), XCIX, Nos. 3–4, p. 183, 1923. (In Russian.)

ANONYMOUS, "Review of the Russian Petroleum Industry, by Fields, Oct. 1921–Sept. 1922." *Neftianoe i Slantzevoe Khoziasitvo* (Moscow), IV, No. 1, pp. 162–177, 1923. (Text in Russian.)

SEVASITANOV, D., "The Cold and Hot Waters of the Grozny Region." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 5–8 (14–17), 1923, pp. 66–74, 1923.

I.S., "Petroleum Reserves in the Uralsk District." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 3–4 (12–13), 1923, pp. 10–13, map, 1923. (Text in Russian.)

SELSKY, V., "A Study of Petroleum in Sedimentary Deposits in Connection with the Petrographic Structure of the Beds of the Grozny Petroleum Region." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 7–9, 1922, pp. 55–60; Nos. 1–2 (10–11), 1923, pp. 52–62, 1923. (Text in Russian.)

SHAPOVALOV, A., "A Generalized Section of the Old Grozny (Staro-Grozny) Petroleum Deposits." *Groznenskoe Neftianoe Khoziaistvo* (Grozny), Nos. 5–8 (14–17), 1923, pp. 62–66, 1923. (Text in Russian.)

SHERIDAN, J. F., "Petroleum Possibilities in Venezuela, Exploration and Actual Development." *Oil, Paint, and Drug Reporter* (New York), CIV, No. 16, pp. 20, 44E, 1923.

SINCLAIR, JOSEPH H., and BERKEY, CHARLES P., "Cherts and Igneous Rocks of the Santa Elena Oil Field." *Mining and Metallurgy* (New York), IV, No. 200, pp. 424–425, geologic sketch map, 1923.

ANONYMOUS, "El Sosneado." *La Riqueza Minera de Chile* (Santiago de Chile), 1st year, No. 4, pp. 64–66, 1922.

STANLEY, E. R., "Geology of New Guinea, Papua," *Annual Report for the Year 1921–22*, pp. 92–94 (Melbourne), 1923.

TEISSEYRE, W., "The Importance of the Trans-Carpathian Dislocations for the Geographic Distribution and the History of the Development of the Petroleum Deposits." *C. R. des Séances du Service Géol. de Pologne* (Warsaw), No. 4, 1922, pp. 2–8, 1922. (In Polish.)

THOMPSON, A. BEEBY, "Oilfield Waste." *Inst. Petroleum Tech. Jour.* (London), IX, No. 38, pp. 311–329, 1923.

THWAITES, R. E., "The Production of Liquid Fuels from Oil Shale and Coal in Australia." *Australia Inst. Sci. and Ind.* (Melbourne), *Bull. No. 24*, 62 pp., 1923.

TYCHININ, B., "On the Photo-chemical Properties of the Heavy Kaluźskaja Petroleum" (a contribution to the methods of determining the "solid" asphalt). *Neftianoe i Slantzevoe Khoziaistvo* (Moscow), IV, No. 1, pp. 73–82, 1923. (Text in Russian; English summary.)

VALGIS, V. K., and MAGUID, M., "On the Utilization of Nitrogen Contained in Russian Shales." *Neftianoe i Slantzevoe Khoziaistvo* (Moscow), IV, No. 1, pp. 88–97, 1923. (Text in Russian, English summary.)

ANONYMOUS, "The Vanadiferous Bitumens of Peru." *Petroleum Times* (London), X, No. 246, p. 432, 1923.

WICHMANN, RICHARD, "Einige neue geologische Beobachtungen im östlichen Neuquen und im angrenzenden Territorium Rio Negro." *Geol. Rundschau* (Berlin), III, pp. 326–345, 1922.

ANONYMOUS, "Yacimiento petrolífero de Bariloche." *La Riqueza Minera de De Chile* (Santiago de Chile), 1st year, No. 5, pp. 80–81, 1922.

ZUBER, S. R., "Eruption of a Mud Volcano on the Island of 'Loss' in the Caspian Sea, February 8, 1923." *Azerbaidzhanskoe Neftianoe Khoziaistvo Baku*, No. 4 (16), pp. 92–108, map, April, 1923. (In Russian.)

BERTRAND L. JOHNSON[1]

[1] Compiled with the assistance of Miss L. M. Jones.

THE ASSOCIATION ROUND TABLE

WHY IS AN EDITOR?

One of the principal things that the Association does is to publish the *Bulletin*. In fact, it is the most useful and most lasting expression of the Association, for it represents the brains and the scientific accomplishments of the members. For these reasons nothing is too good for the *Bulletin* and no effort should be spared to make it as good as possible. No member should fail to do his utmost to maintain the *Bulletin's* high standard; no member should resent what someone else does to this end.

These observations are prompted by the fact that some members seem to be sensitive to editorial criticism of their papers. This is surprising when one considers the fact that we are all working for the same result. Everyone knows that a scientific publication must have and maintain certain rules of capitalization, punctuation, and grammatical construction, and certain standards of clarity, conciseness, and precision of statement. Usage may sanction variations from these rules and standards, but in any one publication a single set of rules and standards must be followed more or less rigidly. It follows that the writings of even the best authors may require editing, to bring them into uniformity with the particular publication in which they are to appear. It is obvious, also, that the editor, with a fixed space at his disposal, may have to condense or even delete, and that his judgment must be supreme as to the space to which any given paper is entitled.

In addition to these matters of form, the papers for such publications as the Association *Bulletin* deserve the closest and most constructive scrutiny as to substance. Fairness both to the *Bulletin* and to the author requires that his paper be studied by some member familiar with the subject-matter and that suggestions be made as to incorrect statements, inaccurate reasoning, or facts or factors that have been overlooked. Such criticisms improve the value of the individual paper, increase the prestige of the author, and maintain the high scientific standard of the *Bulletin*.

To meet these needs, both as to form and substance, the Association has gradually built up a splendid editorial staff. It consists of the editor, associate editors familiar with each of the principal districts of the United States, and associate editors familiar with various theoretical phases of oil geology. Every paper receives the editing of the editor and one or more associate editors. In addition, it receives the editorial scrutiny of Miss Heath of the University of Chicago Press, who is a specialist on typography, proofreading, and grammatical construction. By the time a paper has passed through this mill, the writer has a right to feel proud of it and the *Bulletin* in which it is published.

And yet some writers seem to resent the editing of their manuscripts. It seems to wound their pride, and those whose papers need the most editing are the ones who seem most to resent it. Human vanity may make each of us feel that he writes better and expresses himself more clearly than most other people, and that for someone (who cannot possibly be so well qualified) to suggest change is presumptuous as well as irritating.

Be it so. Undoubtedly we are everyone of us absolutely right. But the facts remain that editing is a necessary evil; that ninety-nine times out of every hundred it improves the paper edited; that it is done solely for the purpose of making the *Bulletin* the pride and joy of every member; that it is thankless work for which the editorial staff should receive thanks rather than resentment; and that the Association requests and urges the staff to edit to the limit.

MAX W. BALL

THE CALIFORNIA MEETING

On Thursday, September 20, 1923, geologists from nearly every part of the United States assembled at the Alexandria Hotel in Los Angeles for the California meeting of the American Association of Petroleum Geologists. When this meeting was first planned last winter, it was doubted whether many geologists outside of California would attend. The expectations of the California members were more than fulfilled as the numerous favorable replies to the questionnaires came in. There was no lack of attendance during the meetings and, although the hall seated over 400 people, standing room only was to be had at several of the sessions.

Registration at the Alexandria Hotel, headquarters, was in charge of Secretary C. E. Decker, assisted by Mrs. Ada E. Mastbrook and Earl M. Price.

The meeting was opened by R. P. McLaughlin, general chairman of the California Committee, who extended greetings to the visiting geologists. President Max W. Ball replied and then took charge of the program. Due to the large number of papers and the limited amount of time for their presentation and discussion, but few of the papers were able to be given in full. This proved to be rather disappointing as all of the subjects given were of timely and universal interest. During the first day the papers dealt mainly with an outline of the general geology of California and a discussion of the Los Angeles Basin oil fields. A visit to the California State Mining Bureau office, where peg models of all the fields were exhibited, gave the visiting geologists a good idea of the structures of the fields to be seen on the following day. No especial entertainment was scheduled for the first night.

A special feature of this meeting was the field excursion for all members, guests, and their families, which took them through some of the important oil fields in the Los Angeles region. About 125 people left the Alexandria Hotel in five large sight-seeing busses at eight o'clock Friday morning, and drove to Signal Hill where the geology of this field was explained by H. H. Dubendorf

and J. E. Elliott. An opportunity was also had to collect, in highly upturned Pleistocene strata, shells which may be found today on southern California beaches. Santa Fe Springs was reached at noon, where Mr. and Mrs. Chauncey D. Clark held open house in their charming Spanish home situated in the midst of the oil derricks. After an inspection of a flowing well near by and a hearty lunch provided by the Committee on Field Trips, the journey was resumed to Puente Hills via the Coyote Hills oil fields. At Brea Canyon producing wells drilled into nearly vertical Miocene strata along a fault were seen, and also a chance was given to those inclined to do a little geologic work on foot. The field was explained by George A. Macready, W. A. English, and R. B. Moran. The return trip was made through Whittier and past the Montebello oil field, reaching Los Angeles at five o'clock. Besides being a most enjoyable trip, it afforded an excellent chance to become better acquainted.

About 300 members and guests attended the banquet at the Alexandria Hotel on Friday evening. During the half-hour preceding the dinner, an informal reception was held in one of the hotel parlors. Each table was put in charge of a local member who was charged with getting a representative crowd at his table, which plan served to get everyone better acquainted. R. P. McLaughlin acted as toastmaster and introduced as speakers J. Elmer Thomas, E. De Golyer, Max Ball, R. L. Dudley, and Thomas O'Donnell. Several stunts were given, including songs by the bunch from Tulsa, which had just arrived, having been delayed in Arizona by washouts. The program concluded with a clever one-act playlet written and given by Ira Remsen, aided by Harry R. Johnson, Sam Perry, and Jack Sickler.

After a day of sight-seeing everyone returned Saturday to the two full sessions of the regular program with full interest. The main topic of discussion centered on the present situation in the oil industry in which geologists from all parts of the country took part.

During the sessions on Saturday the visiting ladies were entertained by the wives of the local members with a visit to the Fairbanks-Pickford studio in Hollywood, where the set for the Douglas Fairbanks picture "Bagdad" was seen. Luncheon was served at Marcel's in Pasadena, after which a drive was taken through the fine residence districts.

On Sunday, the last day of the regular program, a trip in private cars was taken by about 125 members and guests through some of the Santa Clara Valley and Ventura oil fields. The route taken went through Newhall Pass, past the old Elsmere Canyon field, and thence down Santa Clara Valley, where a good section of Miocene and Pliocene strata are exposed, to Santa Paula. Crossing to the south side of the valley, the cars climbed 500 feet up to the South Mountain oil field of the Ventura Refining Company. This is one of the most picturesque fields in the world, where derricks are perched on the steep slopes of a badland country, cut into varied-hued strata of probable Oligocene age. This field was explained on the ground by Frank S. Hudson. Leaving Santa Clara Valley the road to Ojai Valley was taken, which led up

Sulphur Canyon past a well-exposed fault between Miocene and Pliocene rocks, huge oil seeps, one of E. L. Doheney's estates, and the Ojai oil field. Luncheon was served under the trees at El Roblar Inn, situated near the foot of the rugged Topatopa Mountains. The Ventura Avenue oil field was next inspected, where J. E. Elliott gave the inside information. From Ventura part of the crowd returned to Los Angeles by Santa Clara Valley, stopping at the old Camulos Ranch to enjoy the hospitality of the owner, Mrs. Cram. This is one of the few original Spanish ranch houses remaining in California and was the setting for a large part of the story of "Ramona." Others of the party who wished to see more geology returned by Simi Valley, Santa Susana Pass, and San Fernando Valley.

The post-session trip to San Joaquin Valley was taken by a number of the members and their wives. The journey was made by auto over the scenic "Ridge Route" which crosses the San Andreas Earthquake Rift. The Kern River, Sunset-Midway, and Elk Hills fields were seen the following day. A few continued on as guests of the Shell Company of California, from Taft to Coalinga, where this field was seen to good advantage, exceptionally clear weather prevailing.

William S. W. Kew

Members Present

William L. Ainsworth, Wichita, Kan.; A. L. Arnold, Long Beach, Cal.; Ralph Arnold, Los Angeles, Cal.

Charles L. Baker, Berkeley, Cal.; Max W. Ball, Denver, Colo.; Mowry Bates, Los Angeles, Cal.; Carl H. Beal, San Francisco, Cal.; H. T. Beckwith, Bartlesville, Okla.; G. W. Black, Santa Fe Springs, Cal.; Eliot Blackwelder, Stanford University, Cal.; G. H. Bowes, Monrovia, Cal.; Harold E. Boyd, New York City; A. C. Boyle, Jr., Laramie, Wyo.; E. Call Brown, Los Angeles, Cal.; J. B. Burnett, Puerto Mexico, Ver., Mexico; John E. Burtt, Shell Co., Cal.

W. R. Calvert, Los Angeles, Cal.; J. B. Case, Los Angeles, Cal.; J. L. Chase, Long Beach, Cal.; H. S. Clark, Upland, Cal.; R. E. Collom, San Francisco, Cal.; K. H. Crandall, Los Angeles, Cal.; A. F. Crider, Shreveport, La.; A. A. Curtice, Whittier, Cal.

E. F. Davis, Glendale, Cal.; C. E. Decker, Norman, Okla.; Alexander Deussen, Houston, Tex.; E. DeGolyer, New York City; F. W. DeWolf, Dallas, Tex.; E. T. Dumble, Houston, Tex.

Fanny C. Edson, Stanford University, Cal.; J. E. Elliott, Los Angeles, Cal.; W. A. English, Los Angeles, Cal.; E. L. Estabrook, Casper, Wyo.

R. N. Ferguson, Los Angeles, Cal.; C. A. Fisher, Denver, Colo.; Douglas Fyfe, Los Angeles, Cal.

H. S. Gale, Washington, D.C.; James H. Gardner, Tulsa, Okla.; E. G. Gaylord, San Francisco, Cal.; G. C. Gester, San Francisco, Cal.; S. H. Gester, San Francisco, Cal.; W. C. Giffin, Long Beach, Cal.; Herman Gunter, Tallahassee, Fla.

D. S. Hager, Houston, Tex.; T. S. Harrison, Denver, Colo.; T. K. Harnsberger, Tulsa, Okla.; Burton Hartley, Los Angeles, Cal.; P. S. Haury, Los Angeles, Cal.; A. S. Henley, Houston, Tex.; Stanley C. Herold, Stanford University, Cal.; Robert T. Hill, Dallas, Tex.; E. T. Hodge, Eugene, Ore.; H. W. Hoots, Palo Alto, Cal.; F. S. Hudson, Los Angeles, Cal.; Emile Huguenin, Santa Paula, Cal.; Stirling Huntley, Los Angeles, Cal.

Joseph Jensen, Los Angeles, Cal.; E. L. Jones, Jr., Ponca City, Okla.

F. B. Kelsey, Bakersfield, Cal.; L. E. Kennedy, Tulsa, Okla.; W. S. W. Kew, Los Angeles, Cal.; Arthur Knapp, Philadelphia, Pa.; J. K. Knox, Houston, Tex.

B. W. Laird, San Francisco, Cal.; B. H. Lasky, Tulsa, Okla.; James O. Lewis, Tulsa, Okla.; J. V. Lewis, New Brunswick, N.J.; Wayne Loel, Los Angeles, Cal.; E. D. Lynton, Los Angeles, Cal.

C. R. McCollom, Los Angeles, Cal.; R. P. McLaughlin, Los Angeles, Cal.; Angus McLeod, Shreveport, La.; A. N. Mackenzie, Casper, Wyo.; George A. Macready, Los Angeles, Cal.; E. A. Markley, Guthrie, Okla.; S. L. Mason, Pittsburgh, Pa.; Rebecca B. Masterson, Houston, Tex.; A. R. May, Ventura, Cal.; W. C. Mendenhall, Washington, D.C.; F. C. Merritt, Los Angeles, Cal.; H. E. Minor, Houston, Tex.; Joseph E. Morero, Los Angeles, Cal.; Robert B. Moran, Los Angeles, Cal.

H. F. Nash, Tampico, Mexico; W. A. Nelson, Nashville, Tenn.; W. H. Nelson, San Francisco, Cal.; J. M. Nisbet, Bartlesville, Okla.; E. D. Nolan, Los Angeles, Cal.

C. B. Osborne, Los Angeles, Cal.; R. M. Overbeck, Los Angeles, Cal.

R. M. Phelps, Brea, Cal; Sidney Powers, Tulsa, Okla.; W. E. Pratt, Houston, Tex.

R. D. Reed, Palo Alto, Cal.; R. A. Reynolds, Eastland, Tex.; R. W. Richards, Washington, D.C.; D. T. Ring, El Dorado, Ark.; Heath M. Robinson, Dallas, Tex.; G. S. Rollin, Tulsa, Okla.

W. W. Scott, Long Beach, Cal.; Julius Segall, Minneapolis, Minn.; C. L. Severy, Tulsa, Okla.; J. M. Sickler, Los Angeles, Cal.; F. M. Smith, Los Angeles, Cal.; Walter Stalder, San Francisco, Cal.; Willis Storm, Red Bluff, Cal., Ben K. Stroud, Los Angeles, Cal.; John B. Stevens, Fellows, Cal.; George O. Suman, Oil Center, Cal.; John R. Suman, Houston, Tex.

J. A. Taff, Palo Alto, Cal.; N. L. Taliaferro, Los Angeles, Cal.; W. T. Thom, Jr., Washington, D.C.; C. R. Thomas, Tulsa, Okla.; J. E. Thomas, Chicago, Ill.; F. G. Tickell, Stanford University, Cal.; C. W. Tomlinson, Ardmore, Okla.

B. H. Vander Linden, The Hague, Holland; W. A. Ver Wiebe, Schenectady, N.Y.

Bruce Wade, Tampico, Mexico; Carroll M. Wagner, Los Angeles, Cal.; W. L. Walker, Denver, Colo.; C. H. Wegemann, Denver, Colo.; I. C. White, Morgantown, W.Va.; W. B. Wilson, Tulsa, Okla.

VISITORS PRESENT

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A. Davis, Los Angeles, Cal.; E. Deane, El Dorado, Ark.; Mrs. C. E. Decker, Norman, Okla.; E. L. DeMaris, Santa Monica, Cal.; John F. Dodge, San Francisco, Cal.; R. L. Dudley (Paul Peebles), *Oil Weekly*, Houston, Tex.; A. J. Drepenbrock, Long Beach, Cal.; A. E. Dutton, Los Angeles, Cal.

George R. Elliott, Los Angeles, Cal.; R. S. Eskridge, Los Angeles, Cal.

C. K. Fiedler, Pasadena, Cal.; P. A. Foster, Los Angeles, Cal.; Kip Frederic, British West Indies; I. B. Funk, Alhambra, Cal.

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E. L. Ickes, Zelzah, Cal.

Harry Johnson, Los Angeles, Cal.; F. D. Jones, Los Angeles, Cal.

C. L. Kaiser, Taft, Cal.; L. C. Karrick, Los Angeles, Cal.; Mrs. L. E. Kennedy, Tulsa, Okla.; Richard C. Kerr, Long Beach, Cal.; William D. Kleinpell, San Francisco, Cal.

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Lee, La Mirada, Cal.; H. W. Lee, Los Angeles, Cal.; Ralph B. Lloyd, Los Angeles, Cal.; H. W. Lourie, Jr., Denver, Colo.; R. G. Lyans, Pasadena, Cal.

Philip C. McConnell, Whittier, Cal.; N. R. McKee, Cal.; A. C. McLaughlin, Los Angeles, Cal.; Ernest Marquardt, Casper, Wyo.; Hugh B. Martin, Santa Monica, Cal.; Ada E. Mastbrook, Los Angeles, Cal.; Donald E. Mathes, Long Beach, Cal.; Edward Meents, Santa Monica, Cal.; Clement I. Meserve, Los Angeles, Cal.; Doska Monical, Los Angeles, Cal.; G. B. Moody, Berkeley, Cal.; Arthur Moore, Queensland, Australia; W. E. Moore, Pasadena, Cal.; Frank A. Morgan, Los Angeles, Cal.; J. E. Morris, Los Angeles, Cal.; F. L. Morris, San Francisco, Cal.

L. E. Nebergall, Denver, Colo.; Andrew Neff, Chicago, Ill.; W. T. Nightingale, Calcutta, India; E. B. Noble, Maricopa, Cal.; L. F. Noble, Valyermo, Cal.

Penny, London, England; Samuel S. Perry, Los Angeles, Cal.; S. E. Phippen, Los Angeles, Cal.; Rudolf R. Pollak, Maricopa, Cal.; G. H. Poole, Los Angeles, Cal.; D. J. Pope, Los Angeles, Cal.; R. R. Porterfield, Santa Monica, Cal.; Henry F. Power, Santa Fe Springs, Cal.; Colonel J. A. Puffinburg, Los Angeles, Cal.

Aylmore Reeves, Jr., Fillmore, Cal.; F. J. Rice, Los Angeles, Cal.; N. C. Richardson, Pasadena, Cal.; T. A. Rickard, San Francisco, Cal.; John H. Robertson, Orange, Cal.; Mrs. Lillian M. Robinson, Los Angeles, Cal.; Bert Russell, Pasadena, Cal.

Major L. I. Samuelson, Los Angeles, Cal.; C. O. Sanford, Mexico, D. F.; D. F. Schindler, Los Angeles, Cal.; A. T. Schwennesen, Los Angeles, Cal.; Hoyt Sherman, Los Angeles, Cal.; W. H. Shockley, Los Angeles, Cal.; Milton Siegel, Los Angeles, Cal.; R. Simmons, Los Angeles, Cal.; W. A. Sinsheimer, New York City; C. J. Smith, Coronado, Cal.; F. W. Smith, Santa Barbara, Cal.; Ralph M. Smith, Los Angeles, Cal.; Warren Du P. Smith, Eugene, Ore.; F. Soemon, Whittier, Cal.; M. H. Soyster, Los Angeles, Cal.; C. G. Staley, San Diego, Cal.; William H. Syme, Los Angeles, Cal.

A. W. Taylor, Los Angeles, Cal.; DeWitt E. Taylor, Los Angeles, Cal.; H. B. Thomson, Los Angeles, Cal.; C. F. Tolman, Stanford University, Cal.; Mrs. C. W. Tomlinson, Ardmore, Okla.; James T. Tucker, Long Beach, Cal.; W. B. Tucker, Los Angeles, Cal.

G. A. Van Diermer, Los Angeles, Cal.; R. E. Vandruff, San Diego, Cal.; A. A. Van Fleet, Riverside, Cal.; H. R. Van Wagenen, Los Angeles, Cal.; Major A. B. Van Wormen, Los Angeles, Cal.; Frederick P. Vickery, Los Angeles, Cal.; R. E. Vivian, Bakersfield, Cal.

Paul Wagner, *National Petroleum News;* C. R. Wahl, Los Angeles, Cal.; C. P. Watson, New York City; Norval White, San Francisco, Cal.; Mrs. H. L. Williams, Missoula, Mont.; M. D. Wilson, Los Angeles, Cal.; J. H. G. Wolf, San Francisco, Cal.; James T. Wood, Jr., San Francisco, Cal.; A. O. Woodford, Claremont, Cal.; E. A. Wyman, Long Beach, Cal.

George S. Young, Los Angeles, Cal.

H. Zinn, Manila, Philippine Islands.

RESPONSE FROM DR. T. C. CHAMBERLIN

In response to a telegram sent by the Secretary-Treasurer to Dr. T. C. Chamberlin, he replied as follows:

"Will you kindly convey to the American Association of Petroleum Geologists my hearty appreciation of their congratulations on the occasion of my eightieth birthday, and beg them to accept my sincerest gratitude."

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

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Roy E. Collom has been appointed regional director for the California district. This completes the list of regional directors. They are:

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OBITUARY

CARL BERNARD HUMMEL

Carl Bernard Hummel, a very promising young petroleum geologist, died at his home in Pleasant Hill, Missouri, March 18, 1923, from Spanish influenza.

He was the son and only child of Mr. and Mrs. B. P. Hummel, of Pleasant Hill, and was born in Florence, Missouri, September 22, 1896.

He graduated from the California, Missouri, High School, valedictorian of his class, and entered the Missouri School of Mines at Rolla, graduating with the class of 1920.

He was a member of Pi Kappa Alpha fraternity, also Theta Tau (professional engineering) and Tau Beta Pi (honorary engineering) fraternities. He was student assistant at the Missouri State Experiment Station for two years, also junior associate member of the American Institute of Mining and Metallurgical Engineers, and associate member of the American Association of Petroleum Geologists as well as a member of the Okmulgee Geologic Society.

Upon graduation from the School of Mines he entered the geology department of the Indian Territory Illuminating Oil Company, at Bartlesville, Oklahoma, as instrument man. He later entered the geology department of the Josey Oil Company as instrument man and worked his way up to the position of geologist with that company, which position he held at the time of his death.

His untimely death has robbed his profession of one of its most brilliant young minds, and his friends and associates of a true companion.

D. H. Radcliffe

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

THE BULLETIN

OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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